SCHLICH'S

MANUAL OF FORESTRY

VOL. V.

FOREST UTILIZATION

BY

W. R. FISHER

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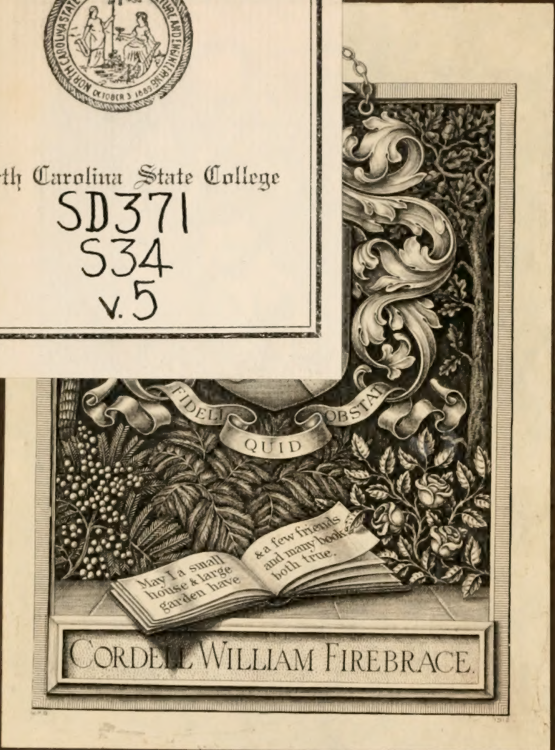
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A

MANUAL OF FORESTRY.

THE MANUAL OF FORESTRY consists of the following volumes:—

Volume I.—INTRODUCTION TO FORESTRY.

,, II.—PRACTICAL SYLVICULTURE, OR FORMATION AND TENDING OF WOODS.

,, III.—FOREST MANAGEMENT.

,, IV.—FOREST PROTECTION.

,, V.—FOREST UTILIZATION.

Volume I. was published in 1889, under the heading "The Utility of Forests and Principles of Sylviculture;" its title was changed as above in the second edition published in 1896; Volume II. was published in 1891; Volume III. in 1895: these three volumes have been written by me. Volume IV. was published in 1895, and this and the present Volume V. have been written by my colleague Mr. W. R. Fisher.

W. SCHLICH.

COOPERS HILL.
May 1*st*, 1896.

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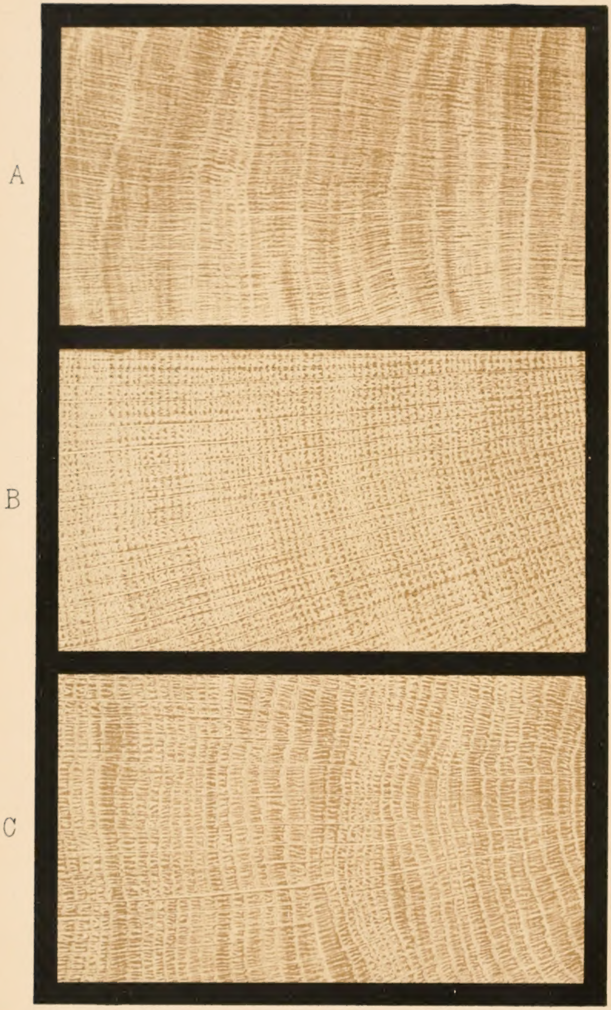
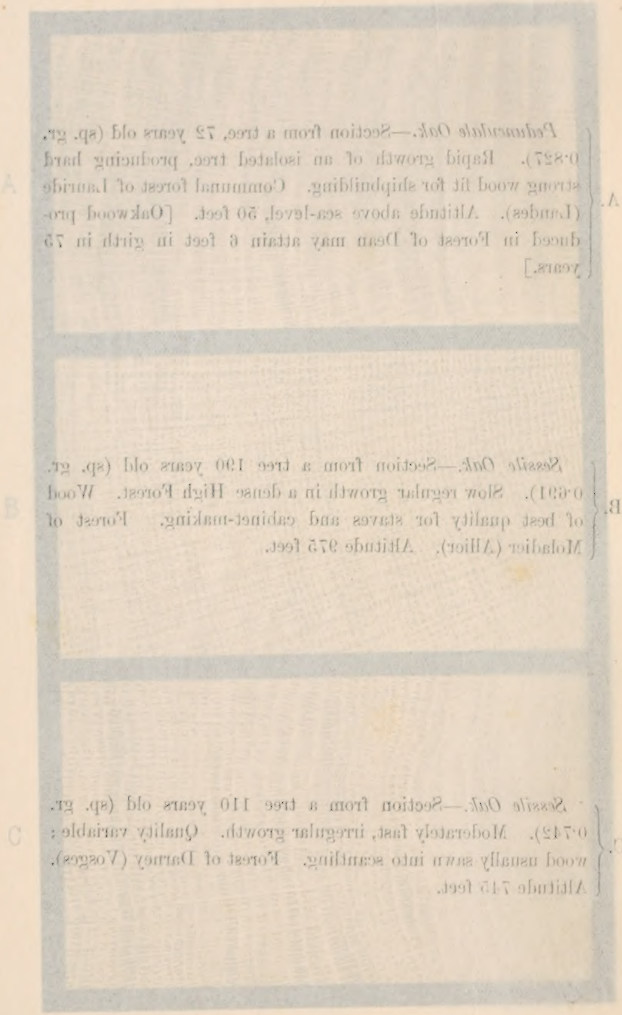


DIFFERENT TYPES OF OAK-WOOD
(Sessile and pedunculate)

A. *Pedunculate Oak.*—Section from a tree, 72 years old (sp. gr. 0·827). Rapid growth of an isolated tree, producing hard strong wood fit for shipbuilding. Communal forest of Lauride (Landes). Altitude above sea-level, 50 feet. [Oakwood produced in Forest of Dean may attain 6 feet in girth in 75 years.]

B. *Sessile Oak.*—Section from a tree 190 years old (sp. gr. 0·691). Slow regular growth in a dense High Forest. Wood of best quality for staves and cabinet-making. Forest of Moladier (Allier). Altitude 975 feet.

C. *Sessile Oak.*—Section from a tree 110 years old (sp. gr. 0·742). Moderately fast, irregular growth. Quality variable; wood usually sawn into scantling. Forest of Darney (Vosges). Altitude 745 feet.



DIFFERENT TYPES OF OAK-WOOD
(Sessile and pedunculate)

SCHLICH'S

MANUAL OF FORESTRY.

VOLUME V.

FOREST UTILIZATION,

BY

W. R. FISHER, B.A.,

ASSISTANT PROFESSOR OF FORESTRY, ROYAL INDIAN ENGINEERING COLLEGE,
COOPERS HILL;
LATE CONSERVATOR OF FORESTS TO THE GOVERNMENT OF INDIA.

WITH 343 ILLUSTRATIONS,

BEING

AN ENGLISH TRANSLATION OF

"DIE FORSTBENUTZUNG," BY DR. KARL GAYER,

PRIVY COUNCILLOR IN BAVARIA, AND PROFESSOR OF FORESTRY AT THE UNIVERSITY OF MUNICH.

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PREFACE.

THE present book, with Dr. Schlich's permission, forms Volume V. of the Manual of Forestry. It is an English translation of the volume on FORSTBENUTZUNG* by Dr. Karl Gayer, Professor of Forestry at the University of Munich, the first edition of which was published in 1863, and the eighth and last edition in 1894. Dr. Gayer's book is the recognised standard German work on the subject of Forest Utilization; although it may appear somewhat detailed for the present condition of British Forestry, yet it is fitting to complete the Manual of Forestry by giving a full account of the economic methods of working forests as they are practised in Continental Europe.

I have added considerably to the original work by notes and illustrations from my own and other experience in Britain, France, and India; the number of plates in the original work (297) has also been increased to 343 in the translation.

Monsieur L. Boppe, the Director of the French National Forest School at Nancy (where I received my first instruction in Forestry), has kindly allowed me the use of many of the plates in his TECHNOLOGIE FORESTIÈRE,† which have been duly acknowledged in the text, wherever they occur. Chapter VIII. of Part III., which deals with resin-tapping, is mainly taken from Mr. Boppe's book.

---

* Die Forstbenutzung, von Dr. Karl Gayer, eighth edition, Berlin. Published by Paul Parey, 10, Hedemannstrasse. 1894.

† A considerably enlarged edition of a work by H. Nanquette, Honorary Director of the Nancy Forest School, Paris, 1887, Berger-Levrault et Cie., 5, Rue des Beaux Arts.

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The last chapter of my book, dealing with the extraction of oil of turpentine and rosin from crude resin, is chiefly taken from papers by Mr. N. Hearle and Mr. E. McA. Moir of the Indian Forest Department which appeared in the *Indian Forester*.

The enormous consumption of timber in North America and elsewhere points to a period in the immediate future when the world-supply of timber will be greatly restricted; it is already the duty of statesmen in all civilized countries to adopt measures for rendering them, in a certain degree, independent in this respect. A careful method of utilizing the resources of their forests is of the highest importance for the vast dependencies of the British Empire, whether in India, Canada, Australasia or South Africa, as well as for the United States. It may therefore be confidently asserted, that the general principles of the economic working of forests, now almost for the first time* expounded in the English language, are applicable wherever that language is spoken.

I have to thank my colleagues, Dr. Schlich and Dr. Matthews, for their kindness in assisting me to revise the proofs, and for some valuable suggestions they have made. Professor Hearson has also helped me in dealing with superstructures (pp. 113—114), and Professor Heath, in the antiseptic treatment of timber (p. 659).

W. R. FISHER.

COOPERS HILL COLLEGE,
May 1st, 1896.

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* The Utilization of Forests, by E. E. Fernandez. Dehra Dun. 1891, is chiefly applicable to India and less comprehensive than the present volume.

TABLE OF CONTENTS.

PAGE

PREFACE v

INTRODUCTION 1

PART I.

HARVESTING, CONVERSION AND DISPOSAL OF PRINCIPAL FOREST PRODUCE.

CHAPTER I.

TECHNICAL PROPERTIES AND QUALITIES OF WOOD.

SECTION I.—ANATOMY OF WOOD.

1. Wood-vessels 6
2. Wood-fibres 6
3. Wood-cells 7
4. Resin-ducts 7
5. Medullary rays 8
6. Annual zones 8

SECTION II.—CHEMICAL AND PHYSICAL PROPERTIES OF WOOD.

1. The woody skeleton of a tree 12
2. Amount of water contained in wood 13
3. Substances in wood, other than water and woody-tissue . . . 14
4. Heartwood and sapwood 15

SECTION III.—SHAPE OF TREES 17

SECTION IV.—SPECIFIC GRAVITY OF WOOD.

1. General account 23
2. Differences due to anatomical structure 25
3. Differences due to substances contained in the tissues . . . 27
4. The different parts of a tree 29
5. Determination of the specific gravity of wood 31
6. Absolute weight of wood 33

SECTION V.—HARDNESS. PAGE
1. Anatomical structure . . . 34
2. Coherence . . . 35
3. Resin . . . 35
4. Degree of moisture . . . 35
5. Action of instruments . . . 36

SECTION VI.—FISSIBILITY.
1. Structure of the wood . . . 39
2. Elasticity and flexibility of fibre . . . 40
3. Moisture . . . 40
4. Locality and mode of growth . . . 41
5. Concluding remarks . . . 41

SECTION VII.—PLIABILITY.
1. General account . . . 42
2. Elasticity . . . 43
3. Flexibility . . . 45

SECTION VIII.—STRENGTH OF TIMBER.
1. General account . . . 46
2. Tenacity . . . 47
3. Resistance to crushing . . . 47
4. Resistance to torsion . . . 47
5. Resistance to shearing . . . 48
6. Transverse strength . . . 48

SECTION IX.—RELATIONS OF WOOD TO WATER.
1. Seasoning of wood . . . 50
2. Absorption of water by wood . . . 52
3. Results of the relations of wood to water . . . 53

SECTION X.—COLOUR AND TEXTURE OF WOOD . . . 59

SECTION XI.—DEFECTS AND UNSOUNDNESS IN TIMBER.
1. Defects in sound wood . . . 61
2. Defects in timber owing to disease . . . 71

SECTION XII.—DURABILITY.
1. General account . . . 79
2. Nature of the wood . . . 80
3. Treatment of wood after felling . . . 84
4. Mode of utilization of the wood . . . 86
5. Classification of woods in order of durability . . . 93
6. Means of increasing the durability of timber . . . 95

SECTION XIII.—HEATING-POWER.
1. Specific gravity of wood . . . 98
2. Amount of water in wood . . . 99
3. Anatomical structure . . . 100

Section XIII.—Heating-Power (*continued*). PAGE
4. Amount of resin in wood . . . 101
5. Degree of soundness . . . 102
6. Determination of heating-power of wood . . . 103

CHAPTER II.

INDUSTRIAL USES OF WOOD.

Sub-division I.—Timber.

Section I.—The Different Classes of Converted Timber.
1. General account . . . 106
2. Logs . . . 107
3. Sawn timber . . . 109
4. Cloven timber . . . 111

Section II.—Timber used in Superstructures . . . 111

Section III.—Timber used on, or in, the Ground.
1. The foundations of buildings . . . 116
2. Wooden water-pipes . . . 117
3. Timber export-works . . . 117
4. Wooden pavement . . . 117
5. Railway-sleepers . . . 118
6. Wood used in forts . . . 121
7. Mining timber . . . 121

Section IV.—Wood used in Contact with Water.
1. Bridges . . . 122
2. Fascines . . . 123

Section V.—Wood used in Machinery . . . 124

Section VI.—Ship and Boat Building.
1. General account . . . 125
2. Species and quality . . . 126
3. Permissible defects . . . 129
4. Shape and dimensions . . . 129
5. Supply of timber for ship-building . . . 132

Section VII.—Joiners' and Cabinet-makers' Work.
1. Joiners' work . . . 133
2. Cabinet-making . . . 134
3. Artistic and fancy ware . . . 135
4. Model-making . . . 135
5. Wood for tools and implements . . . 136
6. Miscellaneous goods . . . 137

Section VIII.—Miscellaneous Uses of Wood . . . 137

PAGE
SECTION IX.—WOOD USED BY THE WHEELWRIGHT 139

SECTION X.—COOPERS' WORK.

1. Casks used for spirituous liquors 142
2. Slack barrels 146
3. Barrels for dry goods 147
4. Barrel hoops 147

SECTION XI.—SUNDRY USES OF SPLIT WOOD.

1. Shingles for roofing, &c. 148
2. Wood for oars and rudders 149
3. Broad split pieces 149
4. Wood-wool 151
5. Slender pieces of wood 151
6. Trenails 153
7. Lead-pencils 153
8. Wood for string musical instruments 154

SECTION XII.—GLAZIERS' WOOD 154

SECTION XIII.—WOOD-CARVING.

1. Coarse wood-carving 155
2. Gunstocks, &c. 156
3. Children's toys 157
4. Artistic wood-carving 157

SECTION XIV.—TURNERY 158

SECTION XV.—PLAITED WOOD-WORK.

1. Basket work 159
2. Wood-plaiting 160

SECTION XVI.—WOOD-PULP.

1. For paper-manufacture 160
2. For other purposes 163
3. Sawdust 164

SECTION XVII.—WOOD FOR AGRICULTURAL PURPOSES.

Sub-division II.—Firewood.

1. Firewood used for its heating power 167
2. Products of distillation of wood 168

Sub-division III.—Woods arranged according to their uses.

1. Woods of broad-leaved trees 169
2. Coniferous woods 171
3. Exotic woods 172

CHAPTER III.

FELLING AND CONVERSION OF TIMBER.

SECTION I.—MANUAL LABOUR. PAGE

1. General remarks 176
2. Demands on the woodcutter 178
3. Wages 181
4. Organization of the labour-gang 187
5. The forest-labour question 190

SECTION II.—WOODCUTTERS' IMPLEMENTS.

1. Hewing implements 193
2. Saws 199
3. Tools for splitting wood 210
4. Implements for extracting and splitting stumps and roots . . 212

SECTION III.—SEASON FOR FELLING 219

SECTION IV.—METHODS OF FELLING.

1. General account 228
2. Different modes of felling 225
3. Felling rules 236

SECTION V.—ROUGH CONVERSION OF WOOD.

1. Mode of conversion 244
2. Timber assortments 248
3. The work of conversion 252
4. Removal of wood before conversion 263
5. Occasional non-conversion of wood 264
5. General rules regarding conversion 264

SECTION VI.—SORTING AND STACKING CONVERTED MATERIAL . . . 265

SECTION VII.—CLEARING THE FELLING-AREA.

1. Explanation of the term 273
2. Purpose of the clearance 274
3. Choice of a forest-depot 274
4. Material to be removed 275
5. Modes of clearance 276
6. Season for clearing a felling-area 288
7. General rules 290

SECTION VIII.—SORTING THE CONVERTED MATERIAL AND FIXING SALE-LOTS 292

" IX.—ESTIMATING THE YIELD 299

" X.—CONCLUDING THE BUSINESS OF FELLING AND CONVERSION 305

CHAPTER IV.

WOOD-TRANSPORT BY LAND.

PAGE
SECTION I.—GENERAL ACCOUNT 308
" II.—FOREST-ROADS 309
" III.—TIMBER-SLIDES 324
" IV.—FOREST-TRAMWAYS 340
" V.—WIRE-TRAMWAYS 352

CHAPTER V.

WOOD-TRANSPORT BY WATER.

SECTION I.—FLOATING.

1. Conditions necessary for streams to be utilizable 358
2. Improvement and maintenance of watercourses for floating wood . 359
3. Booms 385
4. Method employed in floating wood 401

SECTION II.—RAFTING.

1. Rafting-channels 409
2. Rafts 411
3. Dimensions of rafts 416
4. Mode of rafting 417

CHAPTER VI.

COMPARISON BETWEEN DIFFERENT MODES OF TRANSPORT.

1. Conditions of locality 421
2. Wood-assortments 422
3. Cost of transport 422
4. Loss of volume 424
5. Deterioration in quality of the wood 426
6. Influence of railways on the timber-trade 427
7. Canals 428
8. Concluding remarks 428

CHAPTER VII.

WOOD-DEPOTS.

1. Land-depots 429
2. River-depots 431
3. Methods of storing wood 437
4. Registration of receipts of wood at a depot 440

CHAPTER VIII.

DISPOSAL AND SALE OF WOOD.

PAGE
Section I.—Disposal of Wood 441

Section II.—Sale of Wood.
1. Form in which wood is sold 448
2. Various kinds of sale 457
3. Comparison of the various kinds of sale 462

Section III.—Business Principles involved in the Sale of Wood . 467

PART II.

HARVESTING AND DISPOSAL OF MINOR FOREST PRODUCE.

CHAPTER I.

UTILIZATION OF THE BARK OF TREES.

Section I.—General Account 483
,, II.—Production of Young Oak Bark 486
,, III.—Utilization of the Bark of Old Oaks and other Trees 505
,, IV.—Yield in Produce and Revenue of Oak Coppices . 510
,, V.—Other Uses of Bark 515

CHAPTER II.

UTILIZATION OF FOREST FODDER.

Section I.—Pasture.
1. General account 516
2. Production of fodder in forests 518
3. Effect of pasture on forest management, and conditions under which it may be tolerated 522

Section II.—Grass-Cutting in Forests 530
,, III.—Leaf-Fodder 533

CHAPTER III.

FIELD-CROPS IN COMBINATION WITH FORESTRY.

PAGE
Section I.—Methods adopted 536
" II.—National Economic Importance of 541
" III.—Sylvicultural Importance of 543

CHAPTER IV.

HARVESTING THE FRUITS AND SEEDS OF FOREST TREES.

Section I.—For the Artificial Reproduction of Trees.

1. Production of seed by trees of different species 547
2. Season of maturity and fall of seed 550
3. Methods of collecting seed 552
4. Treatment of seed after collection 556
Section II.—Storing the Seeds of Forest Trees 557
" III.—Pannage 563
" IV.—Industrial Uses of Forest Fruits 569

CHAPTER V.

DRY FALLEN WOOD.

1. Quantity available 572
2. Importance from national-economic and sylvicultural aspects . . 574

CHAPTER VI.

UTILIZATION OF STONE, GRAVEL, &c. 576

CHAPTER VII.

UTILIZATION OF FOREST LITTER.

Section I.—General Account 579

Section II.—Importance for Wood-Production.

1. Beneficial effects of litter and humus on the growth of trees . . 580
2. Mode of decomposition of forest litter 587
3. Products of decomposition of the soil-covering 589
4. Summary 591

Section III.—Amount of Litter produced.

1. Dead leaves and needles 592
2. Moss-litter 596
3. Litter from weeds 599
4. Litter from green branches 602
Section IV.—Modes of Harvesting Litter 603

PAGE
SECTION V.—EFFECTS OF THE REMOVAL OF LITTER.
1. Effects on forests 605
2. General physical effects 614
SECTION VI.—VALUE OF FOREST LITTER FOR AGRICULTURE . . . 616
,, VII.—LIMITS TO THE PERMISSIBLE USE OF FOREST LITTER . 622
,, VIII.—MODE OF DISPOSAL AND SALE OF FOREST LITTER . . 628

CHAPTER VIII

RESIN-TAPPING.

SECTION I.—GENERAL ACCOUNT 632
,, II.—SUPPLY OF RESIN FROM THE MARITIME PINE IN THE LANDES OF GASCONY 633
,, III.—TAPPING OTHER SPECIES FOR RESIN.
1. Silver-fir 644
2. Spruce 644
3. Larch 645
4. Black pine 647

CHAPTER IX.

LESS IMPORTANT MINOR PRODUCE.

1. Grass-seeds 649
2. Herbage for various purposes 651
3. Preparation of Scotch pine needles 653
4. Vanillin 653
5. Mosses 653
6. Knoppern galls 654
7. Truffles 654
8. Edible forest fruits 655
9 Lime-bast 656
10. Other items 656

PART III.

AUXILIARY FOREST INDUSTRIES.

CHAPTER I.

ANTISEPTIC TREATMENT OF TIMBER.

1. General remarks 659
2. Materials used for injecting wood 661
3. Methods of injection 663
4. Suitability of different woods for injection 672
5. Results of injection 673

CHAPTER II.

SAW-MILLS.

PAGE

Section I.—General Account 676

,, II.—Forest Saw-Mills 677

,, III.—Steam Saw-Mills 684

,, IV.—Other Wood-working Machines 690

CHAPTER III.

WOOD-CARBONISATION.

Section I.—General Account 693

,, II.—Charcoal-Kilns 695

,, III.—Properties of Good Charcoal and Yield of Different Kinds of Kilns 713

CHAPTER IV.

DIGGING AND PREPARATION OF PEAT.

Section I.—General Account 720

,, II.—Different kinds of Bogs 722

,, III.—Methods of Working Peat-Bogs 725

,, IV.—Drainage of Bogs 729

,, V.—Harvesting the Peat 732

CHAPTER V.

HUSKING AND CLEANING CONIFEROUS SEEDS.

Section I.—Scotch Pine and Spruce Seed 752

,, II.—Larch Seed 765

,, III.—Net Yield of Seed 768

CHAPTER VI.

EXTRACTION OF OIL OF TURPENTINE AND ROSIN FROM CRUDE RESIN.

Section I.—Procedure employed 770

,, II.—Commercial Products obtained from Crude Resin . 773

INDEX 775

FOREST UTILIZATION.

INTRODUCTION.

THE annual produce of forests is the most striking proof of their utility; by its means we are able to satisfy a great number of our wants, and we can never dispense with forest produce, or do so only with the greatest difficulty.

In earlier times, when forests extended far beyond human requirements and unimpaired natural forces maintained them intact without any artificial assistance, Forest Utilization comprised the whole art of Forestry. Protection, tending, sowing and planting, were unnecessary; superabundant supplies of forest produce were available for all possible requirements, and had only to be utilized. This was done for ages, without any regard for economy or for the wants of future generations.

An utterly wasteful utilization of forest produce continued, until a wood-famine was impending; for the demands made by a steadily increasing population on agricultural produce involved the clearance of vast areas of woodland, while the prolonged maltreatment to which forests were subjected had considerably diminished their productiveness. Unfortunately, in many countries, matters have not yet much improved in this respect. If forests are to be maintained, the wood-cutter's axe and the utilization of all forest produce must be brought under control, the forest area densely stocked with trees, and forest utilization subordinated to sylviculture.

Forest raw material may be utilized in various ways, but its utility will be most fully secured when each product is used for

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the purpose for which it is better adapted than any other available material. Then only can a forest respond most fully to the interests of society, as well as those of its owner, for then only will it yield the greatest pecuniary return. There was, however, a time when it was not considered compatible with good forestry to attempt to make a forest yield the best financial results; a forest was looked upon as a means of satisfying, without any speculative motive, the direct and indirect national requirements. But this manner of regarding forests is unsatisfactory, as the importance of any property is most fully recognized and its protection best secured when itself and its produce possess a considerable sale-value. The profit obtained from careful forest-management is small when compared with that from other productive industries, and apparently will not improve, as substitutes for wood come more and more into use. So much the more, therefore, in the interests of both national economy and forestry, should every forest-owner endeavour to increase as much as possible the pecuniary yield of his woodlands, provided that at the same time he works within the bounds prescribed by good forest management. Forest utilization should therefore always keep in view the possibility of a steady improvement of the forest revenue, without prejudice to its maintenance or future enhancement.

The foregoing remarks lead us to define the science of Forest Utilization as *a systematic arrangement of the most appropriate methods of harvesting, converting and profitably disposing of forest produce, in accordance with the results of experience and study.*

Wood is the chief product of forests, and the aim of forest management is at present chiefly directed to its production. Besides wood, there are other useful products, which are derived either from the trees or the soil of forests. As most of them, however, are relatively inferior in value to wood, and their production is bound-up with the existence of forests, they are considered as accessory or minor produce. A distinction is thus made between **principal and minor forest produce.**

A forest owner is, as a rule, only concerned in the rough conversion of the produce of his forest, so as to facilitate its transport. Sometimes, however, and for certain kinds of produce, it may be advisable for him to prepare forest produce in the form in which it is directly utilizable for various industries, in which case he carries-on auxiliary industries depending on forestry. To deal fully with these industries is, however, beyond the province of the present book, and they will be described only in such detail as the ordinary routine of forestry requires.

The matter of which the science of Forest Utilization, thus extended, is composed may be comprised under three principal headings, which are as follows :—

I. HARVESTING, CONVERSION AND DISPOSAL OF PRINCIPAL FOREST PRODUCE.

II. HARVESTING AND DISPOSAL OF MINOR FOREST PRODUCE.

III. AUXILIARY INDUSTRIES DEPENDING ON FORESTRY.

[Owing to the enormous destruction of forests in America and other countries, and the fact that as yet forests are properly managed in only a few countries, there appears to be more reason for hopefulness than Gayer anticipates, as regards the future financial aspect of forestry.—TR.]

PART I.

HARVESTING, CONVERSION AND DISPOSAL OF PRINCIPAL FOREST PRODUCE.

It is impossible to make the best use of any material without a thorough knowledge of its external appearance and inward structure. As every producer endeavours to become acquainted from all points of view with the raw material of which his wares are composed, so that he may render them most useful and increase their sale-value as much as possible, so the forester should—at least, to a certain extent—study the properties and consequent utilities of wood. Only after acquiring this knowledge will he be able to convert and classify his wood, so as to satisfy the demands of the timber-market and obtain for it the best possible price. If he has produced wood of the proper quality and dimensions, the next question is how to dispose of it to the best advantage.

These considerations lead to the subdivision of Part I. into the following five chapters:—

I. Technical Properties and Qualities of Wood.
II. Industrial Uses of Wood.
III. Methods of Felling and Converting Wood.
IV. Transport of Wood.
V. Disposal and Sale of Wood.

CHAPTER I.

TECHNICAL PROPERTIES AND QUALITIES OF WOOD.*

THE wood of our different forest trees has, according to species, very different properties, so that one kind of wood is better adapted for any given purpose than other kinds. The technical properties of any wood are those peculiarities which render it suitable for certain uses. They may vary for one and the same species of tree according to the soil on which the tree has grown, the climate, the rate of growth, the part of the trunk, the age of the tree, the healthy or unhealthy condition of its wood and other circumstances; and even under each of these heads much individuality may be shown.

Hardly any material is so variable as wood, and it is, therefore, impossible to predicate any fixed technical qualities in the wood of a certain species of tree. All we can do is to draw an average, and estimate the influences which may modify this average technical quality of the wood of any particular species.

H. Mayr † lays-down a general rule, that, for every species of tree, the quality and quantity of the wood produced falls-off in proportion to the distance from the best locality for its growth, although the quality of the soil may remain constant.

As all differences in the technical value of wood depend on the variability of its anatomical structure and its chemical and physical nature, it is necessary to consider shortly the anatomy and chemical composition of wood as far as our purpose requires.

SECTION I.—ANATOMY OF WOOD.

Wood consists of three kinds of elementary organs, which do not, however, all occur in the wood of every species of tree—namely, **wood-vessels, wood-fibres** and **wood-cells.**

---

* *Vide* Laslett's Timber and Timber Trees, edited by Marshall Ward, 1894.

† Die Waldungen von Nordamerika, Munich, 1890, p. 73.

1. **Wood-vessels** are more or less narrow tubes closed at their ends, which run longitudinally through the stem and branches of trees. Their walls are thin when compared with their **lumina**, or hollow interiors, and the latter appear as pores on transverse sections of the wood.

Each annual zone of broad-leaved trees contains more or less numerous vessels, the distribution of which among the other elementary organs of the wood affords excellent characteristics for distinguishing the different species. The pores may be uniformly distributed throughout the annual zone, or arranged in bands or wavy lines, in which their size usually decreases towards the outer limit of the zone. In the case of many broad-leaved trees the wood formed in the early-growing season, or **spring-wood**, is rich in large vessels, and may be termed **ring-pored wood**; it contains less woody substance than the **summer-** or **autumn-wood** of the same annual zone. Coniferous wood possesses vessels, and consequently, pores, only immediately around the pith.

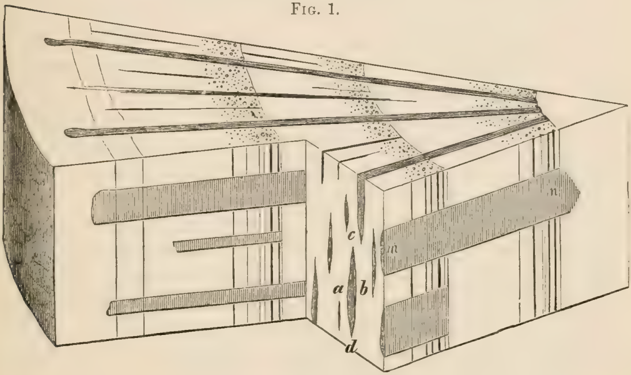
2. **Wood-fibres** are the chief constituents of wood; they are elongated, closed organs, a few millimeters long and pointed at both ends, and their walls are more or less thickened, sometimes so much so that their lumina are greatly contracted. There are three kinds of wood-fibres: **tracheids**, with large lumina and large bordered pits on their walls; **true wood-fibres**, forming **sclerenchyma**, or hard tissue, composed of thick-walled elements, with small pits on their walls; **intermediate fibres**, resembling wood-fibres in shape, but containing protoplasm and starch, &c. The two former kinds of fibres, as well as wood-vessels, serve to convey air and watery sap throughout the plant.

Coniferous wood contains tracheids only, which are thin-walled in the spring-wood, and have large lumina. Tracheids become thicker-walled and more compressed, with smaller lumina, towards the boundary of the annual zone in the summer-wood. As the radial section of these organs is much thinner than the tangential section, they are sometimes termed **broad fibres**.

Broad-leaved wood, on the contrary, often possesses several kinds of wood-fibres, and then the tracheids and intermediate fibres are much thinner-walled than true wood-fibres. The more the latter predominate, the harder and firmer the wood. In oakwood, for instance, thin-walled tracheids are chiefly formed near the vessels, whilst the true wood-fibres form most of the harder summer-wood and are more numerous, the broader the annual zone.

3. **Wood-cells** forming **parenchyma**, or soft growing-tissue, are more or less thinly walled and nearly isometric cells, usually with flat ends, and superposed one above the other like bricks; they contain starch, at least in the younger wood, for the greater part of the year. They are thus the store-chambers for reserve nutrient material, which may be used in ensuing years for forming leaves, flowers and shoots.

Fig. 1.



Wood-cells are chiefly found near the vessels, but often, as for instance in oakwood, form concentric lighter-shaded zones in the darker and harder summer-wood.

In coniferous woods, wood-cells are either entirely wanting or found only around the resin-ducts, or are scantily scattered among the tracheids, as in juniper-wood.

4. **Resin-ducts** are spaces without true walls, surrounded by resin-forming cells; they run not only parallel to the axis of the tree, and are then visible on transverse sections, chiefly in the

summer-wood, but also pass along the medullary rays, which are described in the next paragraph. The two kinds of ducts open into one another, and their contents have important effects on the technical properties of wood.

5. **Medullary rays** (fig. 1) consist of woody cells, which in winter usually contain starch; they form bands, either running radially from the pith to the bark, or not reaching as far as the pith, but originating from some of the later annual zones of wood. The number and size of these rays have much influence on the technical properties of wood.

As regards the dimension ot a ray, *c d* (fig. 1) is its height, *a b* its breadth, and *m n* its length. The oak and beech have very **broad** rays; the oak and alder very **high** rays. These species are also characterized by possessing a large number of small rays besides their large ones. Maple, ash, elm, plane, teak and hornbeam,* have moderately broad rays. Most European woods have narrow rays, which may, however, be clearly seen on thin transverse sections of the wood, as in lime, birch, robinia, horse-chestnut, sweet chestnut, hazel, alder, apple, cherry, &c.; in the case of willows and poplars, however, it is difficult to distinguish the rays without a magnifying-glass; in conifers they are extremely narrow and crowded together, giving a characteristic silky gloss to a thin transverse section of the wood.

From fig. 1 it is clear that, in order to ascertain the structure of a piece of wood, sections of it in three different directions at right angles to one another should be examined. The section cut at right angles to the axis of the tree is termed **transverse,** the **radial section** is parallel—and the **tangential section** at right angles to—one of the medullary rays. The medullary rays, vessels, wood-fibres and cells, may be seen in all their dimensions from the above three sections if cut sufficiently fine and observed either through a magnifying-glass or a microscope of low power.

6. **Annual zones.**—The structure of the annual zones of a piece of wood has considerable influence on its properties, and is

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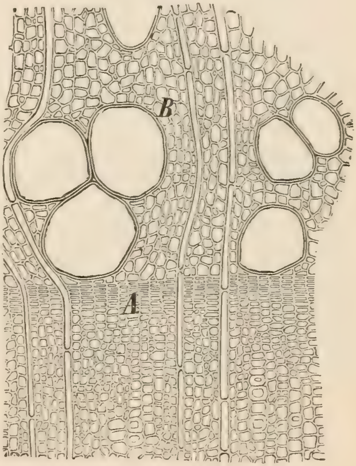
* Hornbeam-wood appears to have very broad rays, because its rays are often crowded together in bundles.

often sufficient to determine the relative value of the wood. The relative dimensions of the spring- and summer-wood, the width of the annual rings, and their uniformity or want of uniformity, should be carefully noted.

(a) *Relative Dimensions of Spring- and Summer-wood.*

If the spring- and summer-wood were similarly organized it would be impossible to distinguish the annual rings on a transverse section of a piece of wood. It has, however, been already noted that in many broad-leaved woods the vessels in the spring-wood are large and numerous, and the wood-fibres wider and thinner-walled than in the summer-wood, in which, usually, the pores are small and the fibres thick-walled. As, therefore, the denser zone of wood *A* (figs. 2, 3 and 4) is immediately adjacent to the porous spring-zone *B*, the boundary of the annual ring is generally very obvious. It is difficult to distinguish the annual rings in woods which form little summer-wood, and with pores which are usually evenly distributed over the whole annual zone, as, for instance, in birch, hornbeam, maples, poplars, alders, limes, horse-chestnut, willows, fruit-trees, &c.

FIG. 2.



Coniferous wood (fig. 4) is without pores; but, on the other hand, the width and thickness of the walls of the summer-wood *A* are very different from those of the spring-zone *B*, so that the annual rings in this case are very sharply defined. As a rule, therefore, annual rings are clearest in the case of ring-pored wood (oak, ash, sweet-chestnut, elm, robinia, &c.), and in coniferous wood.

In coniferous wood from localities suitable for its best growth, the summer-wood is throughout so dense and hard that it differs greatly from the spring-wood, which fact secures for it special qualities, and it has then well-defined annual rings. The more or less gradual passage of spring-wood into summer-wood is sometimes interrupted by the presence of a thin zone of the latter appearing in the middle of the annual zone, which again passes into the usual form of spring-wood and interrupts the regularity of the summer-wood. These are termed **double rings,** and may be ascribed to the action of frost, insect-attacks, drought, &c., causing temporary changes in the tension of the bast and wood in the cambium-zone. Such double or fictitious rings rarely occur in temperate regions, and must be carefully distinguished from the true annual rings.

FIG. 3.

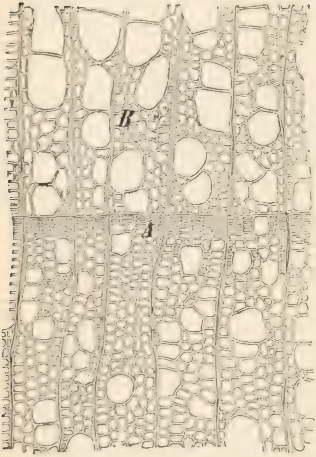
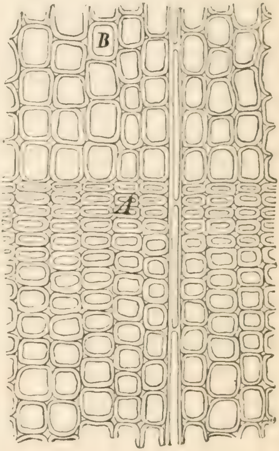


FIG. 4.



(b) *Width of the Annual Rings.*

The absolute width of the annual rings naturally varies considerably under different circumstances: the longer the period of growth, the deeper, moister and more full of nutriment the soil, the greater the amount of light to which the crown of the tree is exposed and of available material from which the wood is constructed;—the wider the annual zone. The most important factor here in the breadth of the annual zones of wood is the amount of light received by a fully-developed crown, as may be at once seen from the broad annual zones of standards over coppice, or of reserved trees left standing after a felling in densely-grown high forest. It is not uncommon, in the latter case, to find that the annual zones of standards increase two- or three-fold, provided the soil has not deteriorated owing to the removal of the other trees in the wood.

Damp years favourable to vegetation yield a larger wood-increment and, consequently, broader annual zones than dry years, and warm, damp years greatly increase the width of the zones of summer-wood. A short period of growth, damage by frost (especially in the case of delicate species), a large production of seed and insect-attacks, reduce the width of the annual zones.*

[Some annual zones are 1 to 1½ inches wide (poplars, willows and some tropical trees, especially *Bombax Malabaricum*), whilst in some trees from 30 to 60 annual zones may occur in an inch of radius. In branchwood the zones are usually narrower, and in rootwood always narrower, than in stems.—Tr.]

(c) *Uniformity of the Annual Zones.*

As a rule, annual woody zones are broader in young trees than in old ones; they therefore become smaller from the centre outwards, even while the sectional area of the zone may remain constant. The pith of a tree is frequently **excentric**, the reason for this being the different width of the annual zones on opposite sides of the stem. This may go so far that a zone may be appreciably present on one side of a tree only, tapering-off quite finely at both ends on the other side. The good quality of timber is more prejudiced by periodical inequality of the annual zones than by this peculiarity. The occurrence of annual zones of the greatest possible regularity is always a sign of good quality in wood. Mohl states that all nearly horizontal branches have excentric zones; in conifers the zones are broadest below, and in broad-leaved trees, above. Large roots, on the contrary, near their junction with the stem, have broader zones above than below, and in their case numerous zones may be absolutely wanting below. In no part of a tree is uniformity of the zones less frequent than in the roots.

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* R. Hartig, Influence of Seed-Years on Wood-Increment. Frst. u. Jgdztng. 1889.

The relative width of the annual zones in the upper and lower parts of stems depends on whether the tree has grown in a dense wood, or in the open. As long as a tree is growing vigorously upwards, and, therefore, usually in a crowded wood, the annual zones are broader in the upper part of the tree than below. The stump of the tree immediately above the roots forms an exception to this rule, for here the broadest rings are formed. In the case of trees grown in the open, standards over coppice and trees with large crowns reserved in high forest felling-areas, the bole tapers from the base upwards; the annual zones may then be uniformly broad above and below, or even broader below than above. In the case of dominated small-crowned trees, the breadth of the annual zones is always broader above than below, and sometimes, owing to an insufficiency of nutriment afforded by their crowns, certain annual zones may be entirely absent below. According, therefore, to the varying effects of density of growth and admission of light on the tree at different periods of its life, there may be a considerable difference in the width of its annual zones.

SECTION II.—CHEMICAL AND PHYSICAL PROPERTIES OF WOOD.

Freshly-felled wood is composed of **woody substance, water,** and **other materials,** some of which are dissolved in the water.

1. The **woody skeleton of a tree**—*i.e.*, the walling of its component organs—is chiefly composed of cellulose and lignin. In the cambium-zone the walls of all elements are of cellulose ($C_6 H_{10} O_5$), but during the very year of their formation the cell-walls become thickened by layers of lignin ($C_{18} H_{26} O_{11}$), which contains more carbon than cellulose: whilst cellulose is soft,

flexible, highly hygroscopic and permeable by fluids ; lignified woody substance is harder, stiffer, and less liable to swell by the absorption of water.

2. There is a **considerable quantity of water in freshly felled wood**—roughly, 45 per cent. of its weight—and this has considerable influence on its technical qualities.

The amount of water contained in wood varies, however, with the species, season, part of the tree, locality, &c.

As regards **species**, broad-leaved wood generally contains more water than coniferous wood.

The **season of felling** has a great influence on the percentage of water in wood, though it is difficult to say at what season any wood will be wettest or driest, as this varies according to species. The air-temperature, the degree of moisture of the soil on which the tree was growing and the condition of the roots, affect this question. In a general way, it may be said that trees contain most water during early summer, and are driest in autumn and late winter. According to R. Hartig's investigations, the following table shows when the wood of different species is wettest and driest :—

Species.	Month of maximum wetness of wood.	Month of minimum wetness of wood.
Birch	March	October.
Oak	July	End of December.
Beech	End of December July	May and October.
Scotch pine	End of December	May.
Spruce	July	March and April.
Larch	July	March and April.

As regards the **part of the tree**, in certain species and especially conifers, the older inner wood is so dry that only the walls of the woody elements contain water, and their lumina none at all. In other species, such as birch and oak, the inner part of the wood is sometimes wetter and sometimes drier than the outer portions, as the wetness of the sapwood varies greatly, according to the season of the year. As a rule, wetness becomes reduced towards the summit of the tree, and the roots contain most water.

The **influence of the locality** (especially the degree of dampness of the soil and the factors of the locality which affect the vital processes in plants) has not yet been thoroughly studied as regards its effect on the amount of water in wood; but it appears as if the facts of trees being shallow or deep-rooted, and possessing, or not, considerable powers of transpiration, are chiefly concerned in the problem.

3. The **substances found in wood other than woody tissue and water** form only a small part of the general mass, and only a few of them influence the technical properties of the wood.

The most important of these substances are **protein**, **tannin** and other colouring matters, **turpentine**, **starch**, and the **ash**, or residue of mineral substances after the wood has been burned.

The **protein** substances, rich in nitrogen, are chiefly found in young, unlignified wood, and especially in the cambium; they readily decompose, and have hitherto been considered as the chief accelerators of decay and rot in wood. **Tannins** are chiefly found in the bark, but are rarely absent from the wood of any species of tree. Their chief property influencing the technical quality of wood is that they corrode iron when the latter is used in contact with wood. Hence teak is preferred to oak for the backing of plates in iron ships, as the tannin of the oak corrodes and loosens the bolts which bind the iron to the wood. **Turpentine**, which is found in varying quantity in the wood of most conifers, and also of certain tropical and semi-tropical broad-leaved species, influences the technical qualities of wood in the highest degree. Turpentine is chiefly found in the resin-ducts, but as these occur in the medullary rays as well as among the tracheids, the whole of the wood may become impregnated with turpentine, which afterwards oxidizes into rosin, especially in the heartwood and roots. The quantity of rosin in wood also varies with the specific gravity of the wood, depending on the greater or less development of summer-wood, in or near which, most of the longitudinal resin-ducts are found.

As regards **starch**, it is found that woody-tissues richest in starch are most exposed to attacks of fungi and wood-destroying insects. The **ash-constituents** of wood are generally more abundant in the younger than in the older wood, [though this is not always the case with woods in tropical countries, where calcium carbonate and calcium phosphate sometimes fill the lumina of wood-vessels in the heartwood.—Tr.] In European trees they predominate in the bark, bast and cambium, and are most abundant in the upper and outer parts of the tree.

4. *Heartwood and Sapwood.**

[The inner and older zones of wood are generally termed **heartwood** and the outer and younger zones, **sapwood** or **alburnum**; these should be distinguished by an actual change in the tissues. Thus, in true heartwood, the walls of the woody elements are charged, and frequently their lumina filled, with colouring matter or with gummy, resinous or mineral substances, which render the heartwood heavier than the sapwood ; if there be any at all, much less starch or protein is contained in the heartwood than in the sapwood, and the former is therefore less liable to attacks of insects and to decay than the latter. Sapwood is fully formed, structurally, from the cambium, but continues to carry-on processes vital to the tree, such as conveying water and reserve nutritive material. Heartwood, on the contrary, may still act as a reservoir for water, but has apparently lost all vital functions, and cannot be usefully injected with creosote or other preservative materials. As a rule, sapwood contains more water than heartwood, and is usually less darkly coloured than the latter ; but these distinctions do not hold for many kinds of wood, and the mere presence of colouring matter in the central parts of certain woods does not indicate any physiological change.

In some trees, the transformation of sapwood into heartwood is very rapid, there being only two or three annual zones of sapwood, whilst in others, as in the oak, there may be from 12 to 45 zones in the sapwood.

It is, therefore, proposed to classify timber as follows :—

(a) **Heartwood trees,** with true heartwood as described above.

i. *Broad zones of sapwood.*

Oaks, elms, walnut, Scotch and other pines.

ii. *Narrow zones of sapwood.*

Sweet-chestnut, robinia, mulberry, fruit-trees, larch, yew.

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* Gayer's account of heartwood and sapwood in trees is less detailed.

(b) **Trees with incomplete heartwood,** in which there is no distinction in colour between the sapwood and heartwood, but the latter contains little or no water and takes no share in the vital processes of the tree :—

Spruce, silver-fir, beech.

(c) **Alburnum trees,** without ascertained distinction between heartwood and sapwood :—

i. *Hardwoods.*

Box, holly, ash, hornbeam, sycamore, maples, plane, birch.

ii. *Softwoods.*

Aspen, lime, alder, horse-chestnut.—Tr.]

Among trees with heartwood, oaks contain more water in their heartwood than in their sapwood, whilst pines and larch have a nearly dry heartwood. As a rule, old trees grown on rich soils have more heartwood than young trees from poor localities.

Up to the present time, no very complete account of the nature of the formation of heartwood is available. Robert Hartig has however written most lucidly on this question for the chief European trees. He holds, in opposition to an old theory, that the colouring of the heartwood is not a commencement of decay, nor a chemical change in the walls of the tissue-elements, but a deposition of tannin, gums, oleo-resins, mineral matter, &c., in their lumina or walls ; hence there is an increase in substance and weight in heartwood, as compared with sapwood. In the case of some woods with imperfect heartwood (alburnum woods), however, the central parts of the tree, as it becomes older, lose weight owing to a loss of starch, or remain unaffected.

The so-called false heartwood (red central zones of beech, &c.) is caused by a commencement of decay, or by the conveyance of soluble products of decomposition from other parts of the tree. The heartwood of old trees is in many species heavier, harder and more durable than their sapwood, which is frequently trimmed off the logs on account of its want of durability. The larger the heartwood in oaks, pines, larch, &c., the more valuable the wood.

As the breadth of the annual zones of wood often causes a considerable difference in the proportion of heartwood and sapwood in the same tree, and broader zones are often formed in youth and narrower zones later on, whilst the breadth of the annual zone has much influence on the density of the wood—it cannot be said that heartwood is always heavier, harder and more durable than sapwood.

SECTION III.—SHAPE OF TREES.

There are technical differences in the wood taken from different parts of a tree, so that a distinction is made between **stem-timber, branchwood** and **rootwood.** Forestry is chiefly interested in the production of stem-timber, for the stem is the chief factor of the timber-harvest, both as regards quantity and quality.

1. The relation between the masses of stem-, branch- and root-wood varies considerably in different trees, principally as regards species, density of crop, age, and quality of locality.

(a) **Species of Tree.**—Each woody species has its own peculiar mode of growth, and no two are alike in shape. There are trees, such as the spruce, silver-fir, larch [and Corsican pine—Tr.], in which, even when grown in the open, the development of the bole predominates over that of the branches. The stem of these trees generally grows undivided straight through the crown to the leading shoot, and the crown consists only of side-branches.

The Scotch pine also at first produces a fine bole, but later on divides into boughs, which are frequently large and numerous forming a spreading crown. In the case of European broad-leaved species, during middle-age and often earlier, the crown gets the better of the bole; amongst these, the alder, sessile oak, ash, poplars, common elm, birch and aspen produce the longest boles.

Speaking quite generally, it may be said that when grown in the open, conifers and light-demanding broad-leaved species yield the best boles.

(b) **Density of Crop.**—The general rule here is that the production of clean boles of mature timber is greatest, and branchwood and to a certain extent rootwood, least, the denser the crop of trees.

Broad-leaved species gain most in this respect from a dense crop, and above all, the beech, hornbeam, and pedunculate oak, the boles of which when grown in the open usually subdivide into boughs at a height of 15 to 20 feet.

It follows that the ratio of the mass of timber in the bole of trees to that of their crown varies according to the system of forest management, and must be much greater under the high forest systems than in coppice-with-standards.

(c) **Age of Tree.**—In considering the amount of utilizable stem-timber in a tree grown in a dense crop, it is evident that during its youth branchwood considerably predominates; when middle-aged, the quantity of stem-timber has already largely increased, and still more so during old age: hence when closely grown, the better species of mature trees yield only 10–20% of branchwood in their total wood-production. It is also easy to see that the amount of rootwood increases with the age of the tree.

(d) **Quality of Locality.**—The amount of useful development of which a tree is capable depends chiefly on the kind of locality where it is growing, so that it may be laid-down as a general rule, that the amount of stem-timber in a tree rises and falls with the quality of the locality. As a rule, the law of root-production is the converse of this, so that the more favourable the soil and climate, the smaller the root-system in proportion to the total mass of the tree.

[In very dry countries, as in Rajputana in India, and New Mexico, species of *Prosopis* develope tap-roots fifty feet and more in length, with very short stems. In these regions farmers dig up the wood they require.—Tr.]

It may readily be conjectured that, owing to the number of factors which affect the ratios between the stem, branch and rootwood of a tree, no constant figures can represent these ratios. In order, however, to give some idea of their value, the following figures, taken from observations made by Pfeil and Hartig and relating to trees grown under favourable local conditions in dense high forest woods, show the relative percentage of wood in the bole, branches and roots of different species of trees.

Name of Species.	Percentage of Wood.		
	Bole.	Branches.	Roots.
Aspen	80—90	5—10	5—10
Birch	78—90	5—10	5—12
Larch	77—82	6— 8	12—15
Alder	75—80	8—10	12—15
Spruce	65—77	8—10	15—25
Scotch pine	65—77	8—15	15—20
Silver-fir	60—77	8—10	15—30
Elm	65—75	10—15	15—20
Hornbeam	60—75	10—20	15—20
Weymouth pine	57—86	5—23	9—20
Sycamore	55—70	10—20	20—25
Beech	55—70	10—20	20—25
Ash	50—65	15—25	20—25
Oak	50—65	15—25	20—25

The proportion of the different kinds of wood in the case of standards over coppice differs very much from the above, as the branchwood predominates until the standards are old. Thus Lauprecht gives the following percentage figures for branchwood of standards of different ages :—

Species.	50—60 years.	60—100 years.	Over 100 years.
Beech	59—60	51	28—40
Oak	58	42	18—25
Aspen	40	40	25—29
Birch	35—40	35—44	34—40

2. **The importance of the shape of the stem from an economic point of view** is very great, and will now be considered. A good stem should be straight, free from branches, and as cylindrical as possible.

(a) **Dimensions.**—Longitudinal growth usually begins to increase in early youth, and culminates in the pole-stage a certain time before the tree bears seed freely. In the horse-chestnut and many tropical and sub-tropical trees, the terminal shoot blossoms; the longitudinal growth is thus eventually arrested, and begins to fall off in all trees after the blossoming period has commenced.

The diameter-growth at first adds less to the mass of the timber than the longitudinal growth, and usually culminates later than it, but continues longer, only terminating with the death of the tree.

The quality of the locality, especially depth of soil, is the chief factor determining the amount of height-growth; the diameter-growth depends also on the amount of light to which the crown of the tree is exposed.

As regards the absolute dimensions of the trees now produced in forests, it may be said as a general rule for Germany, that owing to short rotations, the large timber formerly available is no longer produced. Trees from 130–150 feet high are becoming rarities, and chest-high diameter measurements of 12–16 inches are the average sizes of timber. Anything over 16 inches in diameter may be styled large timber. In some districts, trees measuring 12–14 inches are already classed as large timber.

In order to produce fine timber, both as regards length and diameter, trees should be grown in crowded woods until the principal height-growth has been attained, which will be at about the middle age of the tree; the wood should then be heavily thinned so as to afford room for the crown and roots to develope and thus secure a good diameter-increment, care being taken to keep the soil well covered with undergrowth. Good localities and long rotations should also be selected, and only trees grown which naturally produce large timber.

(b) **Straightness of Stem.**—The axis of the stem of a tree may or may not be in one plane, and if in one plane, it may be in a straight line in that plane. In the latter case the stems are **straight**, the spruce, silver-fir and larch being the straightest trees, and after them the Weymouth-pine, alder and sessile oak. When the axis lies in a plane but not in a straight line, the timber is said to be **curved**, and may be useful in shipbuilding and some other industries.

Timber, the axis of which is not in a plane, or **crooked timber**, is of little use except for fuel.

Density of growth has the greatest influence on straightness of stem. Most broad-leaved species and the Scotch pine which in the open are frequently crooked, when grown in dense woods yield straight timber resembling that of the spruce and silver-fir. Beech, sycamore, sessile oak, ash, and hornbeam, gain greatly in this respect in mixture with other species which help to crowd the wood.

The locality, especially depth of soil, is not without influence on straightness of stem. The Scotch pine alters its shape most of all according to the locality in which it is grown, as while in Norway, Poland, Finland and North Germany it grows as straight as silver-fir and spruce, in the warmer regions of South Germany and France it is often found crooked, even in dense woods. A rapid upward growth during youth is prejudicial to the Scotch pine in this respect, while a steady, moderate, and long-continued upward growth is favourable to its straightness.

Larch trees in the open, or growing rapidly on the borders of dense woods, are often curved and acquire a sabre-like form; this is probably caused by the prevailing wind contending against the soft upward shoots of the trees during youth. Fertile soil and a shallow root-system favour this peculiarity more than poor and stony soil, and the curve is confined to the lower part of the tree.

(c) **Freedom from Branches.**—As soon as the crown of a sapling growing in a crowded wood has been formed, so that its lower branches do not receive sufficient light for their foliage to thrive; they commence dying and dry-up, breaking off from the stem and leaving the latter to a certain height, as a clean bole. This clearance of the lower branches occurs in light-demanders, even when grown in the open. Shade-bearing trees, on the contrary, such as the spruce, may, in the open, retain side-branches down to the ground, and the same may be said of the hornbeam and beech among broad-leaved trees. It is therefore of the utmost importance that a dense growth should be maintained in woods during the whole period of upward growth of the trees. If after this period the trees are allowed more room, this has no influence on the cleanness of their boles, except that epicormic branches, which can easily be pruned, may appear in the case of isolated standard trees.

Cleanness of bole, especially towards its base, is then among the very first conditions for the production of valuable timber. Early closing-up of woods is therefore essential, and all widely spaced planting, especially of shade-bearing trees, should be abandoned. Trees which have freed themselves only late in life from their lower branches will yield very inferior planks and scantling.

It may be possible to secure clearness of bole by means of pruning; but this should be considered only as a last resource, for the soundness of the timber may be thus compromised. Where pruning is undertaken in place of close planting, it must be commenced very early, and continued till the trees are thirty or forty years old: late pruning clears only the superficial parts of the boles from knots, leaving them in its more central portion.

(d) **Cylindrical shape.**—A bole is said to be cylindrical or non-tapering, the more it approaches the cylindrical shape; it is tapering or conical, the more it approaches the shape of a cone. It is easy to see that the more cylindrical a bole, the more useful its timber, and the greater the diameter of the smaller end of a log for the same length, the more valuable it will be. Length, and diameter at the smaller end are therefore better measures of the value of a log, than its cubic contents, or its length and diameter taken midway along its axis.

The absolute measure of the cylindricity of a stem is its **form-factor**, *i.e.*, the ratio of its real volume to that of the **ideal cylinder** of the same height and diameter as the stem (the diameter being measured chest-high). Thus, to take examples: mature silver-fir have form-factors between 0·44 and 0·57, spruce between 0·41 and 0·58, and beech between 0·46 and 0·49.

The more or less cylindrical shape of timber depends chiefly on the species, the density of growth, the height and age of the trees, the nature of the locality, &c. As regards species, it is evident that trees which, when crowded, produce tall boles without much subdivision into branches, especially those which have small branches (silver-fir, spruce, larch and Scotch pine), must have boles more cylindrical than others, such as most broad-leaved species, which have a greater tendency to subdivide into branches. In the case of trees growing isolated in the open, the crown is largely developed and comes low down the bole, so that the nourishment available for the stem from the foliage of the crown increases downwards with the insertion of each bough. The annual zones are therefore often broader in the lower part of the bole than above, and the bole assumes a conical shape. This is most marked in the case of low-branching, isolated spruce trees. In a crowded wood, on the contrary, the crowns of the trees are reduced to the uppermost part of their boles, and this portion therefore obtains more nourishment than their bases; broader annual zones are therefore produced in the upper part of the bole, which approaches in shape to that of a cylinder.

The height of the tree also influences matters in this respect. and Baur has shown that spruce and beech trees increase cylindricity of bole up to 60—75 feet in height, but that where the height exceeds 75 feet, the cylindricity falls-off; so that in closely grown, nearly even-aged woods, the form-factor varies with the height of the trees. A similar relation subsists between the shape of the bole and the age of a tree, as the form-factor falls-off for very old trees, especially after they have been heavily thinned in order that they may put on increment, due to increased exposure to light.

SECTION IV.—SPECIFIC GRAVITY OF WOOD.

1. *General Account.*

The specific weight of wood varies considerably under different conditions, not only according to species, but also to locality and the mode of formation, the age of a particular tree, the part of the tree from which any piece of wood is taken, its degree of moisture, amount of resin it contains, and several other factors.

The mere knowledge of the average specific gravity of any particular piece of wood is not sufficient to determine its weight.

Physicists distinguish absolute from specific weight, the former being determined by a balance, and depending on the pressure due to gravity which a given mass exerts on any object supporting it. The unit of weight is that of 1 cubic centimeter of water at its greatest density, 4° C., and is termed the gram.

Under the term **specific gravity** is understood the ratio which the weight of a certain volume of wood bears to that of an equal volume of water. The specific gravity also indicates how much heavier or lighter any wood is than water, and whether it can be floated or not. Since a cubic centimeter of water weighs a gram, the specific gravity of wood is calculated by dividing its weight in grams by its volume in cubic centimeters. Conversely the absolute weight of a piece of wood can be ascertained by multiplying its volume by its specific gravity.

[As one cubic foot of water at its greatest density weighs 1000 ozs. = 62½ lbs.; multiplying 62½ lbs. by the specific gravity of a wood gives the weight of a cubic foot, or dividing the weight of a cubic foot by 62½ lbs., its specific gravity.—Tr.]

A correct knowledge of the specific gravity of woods does not give much information regarding their economic value, but is of importance where much weight tells on the strength of a structure, as for roofs, machines, wood for carriages, &c.; also as regards the cost of timber transport.

[In India, the great weight of many of the hardest woods, such as the different kinds of iron-wood (*Mesua ferrea*, *Xylia dolabriformis*), &c., renders them unsuitable for floating, and where other transport is not available may altogether prohibit their use. Comparative lightness, irrespective of their inherent good qualities, is one reason for the extensive use of teak and *Cedrela Tuna*; also owing to their light weight many extremely soft woods, such as *Bombax malabaricum*, are used for packing-cases, though their durability is very inferior.—Tr.]

Hardness, durability, heating-power and amount of warping also depend more or less on the specific gravity of woods.

The specific gravity of woody substance, *i.e.*, of the cell-wall, is greater than that of water for all species of trees. According to independent and accordant investigations by Sachs and R. Hartig there is no essential difference between the specific gravity of the substance of the more important woods, as for instance oak, beech, birch, spruce and Scotch pine; the specific gravity of the woody substance of which they are composed may be placed at 1·56. In this respect no difference has been observed between heartwood and sapwood. It is therefore clear that differences in the specific gravity of different woods are due to their anatomical structure, and to the substances contained in the lumina of their fibres and vessels.

Library

2. *Differences due to Anatomical Structure.*

The specific weight of a wood depends chiefly on the character of the lumina of the woody elements—the more abundant they are, the greater their dimensions—and the thicker their walls, the less will be the woody substance and the lighter the particular kind of wood. Hence the greater or lesser quantity of woody substance contained in a given volume of wood is the chief factor in its comparative weight.

In most woods this woody substance is unequally distributed, there being more substance in the summer-wood and less in the spring-wood. It therefore follows that the specific gravity of a wood depends on the ratio of the mass of the summer- to the spring-zones, and wood is so much the heavier, the broader the summer portion of the annual zone.

Evidently a late and short spring and a prolonged summer are favourable to an increase of weight in wood. It is also evident that special localities and seasons will affect the differences between the amount of spring- and summer-wood. Comparative densities of stocking will also affect this question, for in crowded woods vegetation begins later in the spring than in more open woods.

The quantities of woody substance in different woods vary considerably according to species, and to the energy of growth due to local conditions. Amongst the indigenous trees of Central and Western Europe, the oak contains the largest amount, and the silver-fir the smallest, of woody substance; Hartig states that broad-leaved species exceed conifers in this respect by about 25 to 30 per cent.

The energy of nutrition varies with the locality; not only must the soil be considered, with its widely-differing powers of productiveness, but also the powerful aids it receives from heat and light. They are chiefly influential during summer, when they meet with the fullest development of foliage and roots, and most woody substance is therefore formed in summer. The immense importance of these factors on the structure of the annual zones of wood, in localities where the soil is equally productive, is very noteworthy. From the harmonious or discordant working of all the factors of nutrition a number of phenomena arise—for instance, the comparatively high specific gravity of spruce and larch in the Alps, with a short growing season and intense light, when compared with wood of these species from the plains; the high specific gravity of oakwood grown on warm aspects compared with that from cold localities; the low specific gravity of sessile oak on poor, sandy soils; the fine-ringed sprucewood from the higher Alps and the extreme north of Europe; the porous wood produced, especially by the pedunculate oak and elm, when trees are grown in very wet situations; the high specific gravity of some of the broader annual zones of conifers when the trees are isolated and their crowns fully exposed to light.

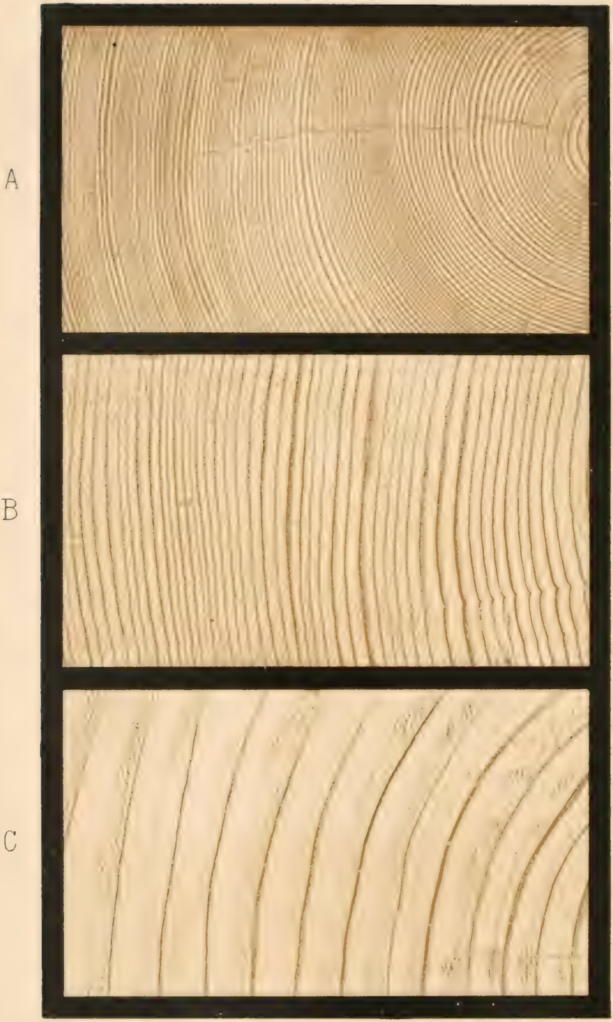
Although it follows from the above that there must be a considerable difference from year to year and from place to place in the amount of summer-wood, the question arises whether the breadth of the ring will alone suffice to decide the specific gravity of a particular wood? This question can be answered only after a study of the different groups of woods. As regards woods which are ring-pored, it may be laid down that quick-grown, wide-ringed wood is denser than narrow-ringed wood, provided that 6 millimeters (¼ inch) is not exceeded. (*Vide* Plate I.)

[As a rule, broad-leaved woods of the same species become heavier when grown more to the south, so that sessile oakwood may be much heavier from Provence than from Normandy.—Tr.]

For wood with evenly distributed pores, the breadth of the rings is no indication of comparative density, the difference between the spring- and summer-wood being so slight. R. Hartig states that the breadth of the annual zones in beechwood has no influence on its specific gravity, which depends on the age of the tree. During youth heavier wood is formed and during maturity lighter wood, as the larger the crown of the tree, the greater the lumina of the woody elements through which the water passes from the roots to the foliage. If, then, superior beechwood is produced in good localities, it is usually because, in such places the rotation is shorter, and the wood felled when it is younger than in inferior localities.

Regarding conifers, long experience has shown that, in the majority of cases, narrow rings imply heavier wood than broad

Pl II



DIFFERENT TYPES OF SPRUCE WOOD

A. Section from a tree 200 years old (sp. gr. 0·627). Slow regular growth in a dense forest. Wood of best quality for cleaving: used for violins, &c. Forest of Chamounix (Haute Savoie). Altitude 4,550 feet.

B. Section from a tree 150 years old (sp. gr. 0·458). Regular structure, even and moderately fast growth. Excellent wood for carpentry and joinery. Forest of Grande Chartreuse (Isère). Altitude 4,420 feet.

C. Section from a tree 35 years old (sp. gr. 0·447). Very rapidly grown wood produced at a low altitude. Soft wood of inferior quality. Forest of Saint Laurent du Pont (Isère). Altitude 1,545 feet.

rings; but there are certain exceptions to this rule, as in the case of sprucewood from high Alpine districts with annual zones only 1 or 2 millimeters broad. Hartig considers that the specific gravity of conifers increases and falls with the volume-increment: this is due to the fact that, with an increasing sectional area, the lumina of the water-conducting organs can be reduced; on the contrary, when the sectional-area increment is reduced, the lumina must be larger. This, however, holds good only for individual trees, and it must not be laid-down as a general rule that larger sectional-area increment always implies heavier wood. (*Vide* Plate II.)

3. *Differences due to Substances contained in the Tissues.*

Among the materials present in woody tissue, **water, resin** and **reserve nutritive material** are the most important, the amount of these substances in the walls and lumina of woody tissue necessarily influencing the specific gravity of the wood.

(a) **Water.**—The weight of water in wood varies, according to species, tree-part, season and locality, between 30 and 55 per cent. of the total weight of the wood, the wood of felled trees being of all degrees of moisture; in practice a distinction is made between **green timber,** with an average of 45 per cent. of water (as is the case if recently-felled trees); **wood dried in the forest,** after lying for some time in breezy forest depots; and, finally, **air-dried wood,** which has been for a long time kept under cover in timber-yards, and retains only 10 to 11 per cent. of water.

For scientific purposes, **absolutely dry wood** is obtained only by placing wood in drying-chambers at a temperature of 105° C. (221° Fahr.) until it no longer loses weight in a sensitive balance. Such a state of dryness is retained only whilst the wood is in the drying-chamber; after removal, it speedily re-absorbs moisture and becomes heavier.

The greater or less volume of water contained by wood also influences its specific gravity indirectly, by its effects on the mass of the wood. As wood dries it shrinks, and shrinkage tends to increase its specific weight.

It has often been asserted that the season of felling has an influence on the specific gravity of wood. If the absolute weight of green wood is in question here, there can be no doubt that, as the amount of water in wood differs at different seasons, to this extent its weight varies. Thus broad-leaved wood contains least water in winter, conifers least during spring, allowance being made for the irregularities in this respect of certain species. The season of felling has, however, no effect on the specific gravity of dry wood.

(b) **Resin.**[*]—In the case of conifers and of many broad-leaved trees of hot countries, resin replaces water in filling-up the lumina of the woody elements. Highly-resinous wood is always considerably heavier than similar wood poor in resin. R. Hartig states that the wood of European conifers[†] differs in this respect: thus the spruce only produces resin in the younger zones of the sapwood, and it is therefore evenly distributed throughout the stem; the Scotch pine also produces resin in mature wood, and its heartwood thus becomes highly resinous. The larch appears to resemble the spruce, and owing to the fluid nature of larch-resin in old trees it tends to accumulate at the base of the tree. In all conifers, however, the specific gravity of the wood increases and diminishes with the quantity of resin it contains.

(c) **Other Substances contained in Woody Tissue.**—It would appear that the different relative quantities of reserve nutritive material (starch, proteins, &c.) which are contained in wood at different seasons might affect its specific weight,[‡] and Th. Hartig believed that in summer a reduction of 5 to 8 per cent. should be made on this account, but R. Hartig has rendered this more than doubtful by his observations on the amount of reserve-material in the wood of oak and beech during summer and winter. These substances, as well as inorganic salts, are chiefly found in bark and sapwood; their influence on the specific gravity of wood is however inconsiderable, even in the case of floated wood, which after drying is not appreciably lighter than wood which has not been floated.

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[*] [By **resin**, the crude material is meant which is found in trees and from which **oil of turpentine** is distilled, **rosin** or **colophany** being left as a residual product.—Tr.]

[†] [As regards exotic trees, the more southern trees are generally most resinous; thus *Pinus australis* (Michaux) in America, and *Pinus Merkusii* in India, yield highly resinous coniferous wood, and *Pinus Pinaster* (Solander) in S.W. France, is more resinous than the Scotch pine.—Tr.]

[‡] [In India, various woods contain deposits in their heartwood which considerably increase the weight of the latter.

Thus in the heartwood of ebony, the lumina of the woody tissue are filled with substances which raise its weight, as compared with the sapwood, in the ratio of 5 : 8.—Tr.]

Wood injected with creosote or metallic salts becomes heavier than uninjected wood, and, according to Nördlinger, creosoted Scotch pine and beechwood gains 17 to 18 per cent. in weight over uninjected wood.

4. *The Different Parts of a Tree.*

The specific weight of wood varies for the different parts of a tree. It may be laid-down as a general rule that branchwood is heavier and rootwood lighter than stemwood. Exceptions occur in the case of the branches of ring-pored wood, when these latter have grown for some time in the shade, their wood then being very light; also in the case of roots of conifers* rich in resin, which are often extremely heavy, rootwood of Scotch pine having sometimes a specific gravity of 1·035. According to Nördlinger, the specific gravity of roots is less, the finer the roots in question.

All wavy wood, burrs, knots of branches and sound growth over wounds, is heavier than ordinary wood; old knots in conifers, with narrow annual zones, are frequently the heaviest parts of the tree.

As regards differences in weight between the older and younger parts of the stem, a distinction must be made between its upper and lower parts, and also between sapwood, heartwood and imperfect heartwood. Regarding these three classes of wood, no general law can be laid down. Premising that the wood is air-dried, and its annual zones regular and of about average breadth, in the case of oak, Scotch pine and larch, the heartwood is heavier than the sapwood. In birch, the inner zones are lighter than the outer ones, and in the case of many species, such as spruce, no marked difference in weight exists between the inner and outer zones.

It will be easily understood that the nature and breadth of the annual woody zones in different trees influence matters

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[* Termed **torch-wood** in India.—Tr.]

here; thus all species, as a rule, form broader rings during youth than in old age.

Owing to differences in the breadth of annual zones in old conifers, the weight of the wood frequently increases outwards; but in ring-pored, broad-leaved trees, and also in beech, the opposite is the case. In young stems there is usually no marked difference between the weight of the inner and outer zones of wood.

In cases of decay of the wood due to parasitic or saprophytic fungi, the weight is always reduced; this must influence the relative weights of heartwood and sapwood.

If we consider the respective weights of the upper and lower parts of stems, much variety prevails, owing to the varying conditions under which a tree has grown at different periods; in the majority of cases, it may be affirmed that the lower part of the stem is heaviest.

It was found by Sanio and R. Hartig for the Scotch pine, and by Exner for the beech, that, owing to the comparatively broad zones of dense summer-wood below and spring-wood above, the lower part of the stem contains heavier wood than its upper part: the wood contained within the crown becomes again heavier.

Hartig also found that, with young oak trees up to 50 years old, the weight of the wood increased upwards. With old and very old oaks, on the contrary, the reverse happened, and this was more frequently the case with trees growing in dense woods than those in the open.

For the birch, R. Hartig made the interesting discovery that the weight of the wood was not affected by the breadth of the rings, but by the age of the part on which the ring occurred; broad rings only appeared to contain less woody substance because they belonged to the younger parts of the tree, and hence the lower wood was heavier.

Spruce and silver-fir grown in dense woods contain heavier wood in the lower portion of their stems, but trees of these species grown in the open, with crowns low down the stem, contain heavier wood above than below. In the Scotch pine the weight of the wood increases with its age, and is influenced by the production in it of resin; the heaviest wood is, therefore, always in the lower part of the stem.

5. *Determination of the Specific Gravity of Wood.*

The determination of the specific gravity of a piece of wood consists merely in measuring its absolute weight in grams and its volume in cubic centimeters, and dividing the former by the latter.* The absolute weight of a piece of wood is measured by the chemical balance, and its volume by the xylometer.† Owing to the important proportion that the contained water always bears to even air-dried wood, the determination of its degree of moisture is highly important in ascertaining its weight. This is most variable in forest-dried wood, although air-dried wood also varies in this respect; as wood is usually employed in this latter condition, figures of the specific gravity of wood, especially when averages are employed, usually refer to air-dried wood.

The determination of the specific gravity of woods is usually undertaken for small pieces only. More recently, however, larger pieces have been used for this purpose, and the specific gravity determined for different parts of a tree. If the object is to ascertain the average specific gravity of a whole stem, the simplest method is to divide it into a number of transverse pieces of equal length and ascertain the specific gravity of each, after it has been thoroughly air-dried, and then take the average specific gravity of them all as that of the stem.

From a consideration of the preceding paragraphs regarding the specific gravity of wood, it is evident that, in dealing with different species of trees, only average figures can be taken; for the specific gravity of any kind of wood ranges within wide limits, independently of the difference between that of heartwood or sapwood, the upper and lower parts of stems, &c.

The following table gives the highest and lowest specific gravity of different woods, as well as its average value. Although such figures can only be of relatively small utility, they give the approximate order of the species as regards the weight of their stem-wood. The results are derived from observations made by Nördlinger, Baur, R. Hartig, Exner, v. Seckendorff and

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[* Or by dividing its weight in thousand ounces by its volume in cubic feet.—Tr.]

† *Vide* Schlich's Man. of Forestry, Vol. III., p. 27.

Gayer himself, and are arranged according to the averages for air-dried wood.

Name of Tree.	Range of Sp. gr.		Average Sp. gr.	
	Green	Air-dried.	Green.	Air-dried.
Hickory	—	—	—	0·89
Turkey oak...........	1·02—1·17	0·83—0·87	1·10	0·85
Yew.....................	·97 –1·10	0·74—0·94	1·03	0·84
Mountain-pine	—	0·72—0·94	—	0·83
Service-tree	0·87—1·13	0·67—0·89	1·01	0·80
Pedunculate oak ...	0·90—1·28	0·54—1·05	1·04	0·76
Ash	0·74—1·14	0·57—0·94	0·88	0·75
Norway-maple	—	—	—	0·75
Sessile oak	0·87—1·16	0·53—0·96	1·01	0·74
Hornbeam	0·92—1·25	0·62—0·82	1·05	0·74
Robinia	0·75—1·22	0·58—0·85	0·87	0·73
Pear-tree..............	0·90—1·07	0·71—0·73	1·05	0·73
Teak	—	0·61—0·86	—	0·73
Beech	0·88—1·12	0·63—0·83	0·98	0·71
Elm......................	0·73—1·18	0·56—0·82	0·95	0·69
Common maple	0·87—1·05	0·61—0·74	0·97	0·69
Apple-tree	0·95—1·26	0·66—0·84	1·01	0·67
Sweet-chestnut	0·84—1·14	0·60—0·72	0·99	0·66
Sycamore	0·83—1·04	0·53—0·79	0.93	0·66
Birch	0·80—1·09	0·51—0·77	0·96	0·65
Larch	0·52—1·00	0·44—0·83	0·81	0·59
Plane	—	—	—	0·58
Horse-chestnut	0·76—1·04	0·52—0·63	0·90	0·57
Black alder...........	0·63—1·01	0·42—0·64	0·83	0·54
Sallow.................	0·73—0·97	0·43—0·63	0·85	0·53
Scotch pine	0·38—1·04	0·31—0·74	0·82	0·52
Aspen	0·58—0·99	0·43—0·57	0·81	0·51
Black pine	0·90—1·12	0·38—0·76	0·97	0·51
White alder	0·61—1·00	0·43—0·55	0·80	0·49
White poplar...... ..	0·80—1·10	0·40—0·57	0·95	0·48
Silver-fir	0·77—1·23	0·37—0·60	0·97	0·47
Spruce..................	0·40—1·07	0·35—0·60	0·76	0·45
Lime	0·61—0·87	0·32—0·59	0·74	0·45
Cembran pine.........		0·40—0·45	—	0·44
Weymouth-pine......	0·55—1·02	0·31—0·56	0·83	0·39
Wellingtonia	—	—	—	0·38

The different woods may be classified as follows according to their specific gravity:—

Very heavy woods (sp. gr. 0·75 *and above).*

Turkey oak, yew, mountain-pine, service-tree, ash, pedunculate oak.

Heavy Woods (sp. gr. 0·70—0·75)

Sessile oak, hornbeam, robinia, pear, beech.

Moderately heavy Woods (sp. gr. 0·55—0·70).

Elm, common maple, apple-tree, sweet-chestnut, sycamore, birch, larch and horse-chestnut.

Light Woods (0·55 *and less*).

Black alder, sallow, Scotch pine, aspen, black pine, white alder, white poplar, silver-fir, lime, spruce, Cembran and Weymouth pines.

6. *Absolute Weight of Wood.*

The absolute weight of any piece of wood may be readily calculated from its specific weight, by multiplying its volume in cubic centimeters by the number representing its specific gravity, the result being in grams. [Also multiplying the sp. gr. of a wood by 62½ lbs. and by its volume in cubic feet will give the weight of a piece of wood in lbs.—Tr.] A knowledge of the actual weight of a piece of wood is most useful in the case of **wood dried in the forest**, as this greatly influences its transportability.

The following figures are taken from weighments actually made by Böhmerle and Vultejus, but it should be remembered that the term **forest-dried** is very elastic.

Oak, Beech, Hornbeam, Ash, Maple and Elm.

	cwt.	lbs.
Solid cubic foot of timber	0	45
Stacked 100 cubic feet of split firewood billets	37	3
Ditto, round billets	33	43
Ditto, rootwood	34	19
100 faggots	66	86

Beach and Hornbeam.

Solid 100 cubic feet of split billets	46	83
Ditto, round billets	45	70

Birch, Aspen, Spruce, Scotch Pine, Silver-fir, Larch and Black Pine.

	lbs.
Solid cubic foot of timber	35⅓
Stacked 100 cubic feet of split firewood billets	2729
Ditto, round billets	2729
Ditto, rootwood	2181

[Thus a load of 40 cubic feet of hardwood weighs 16 cwt. 12 lbs., and a load of 50 cubic feet of softwood weighs 15 cwt. 90 lbs., the cubic meter being reckoned at 35·3 cubic feet and the kilogram 2·2 lbs.—Tr.]

In the German timber-trade a solid cubic meter (*Festmeter*) of wood is reckoned to weigh 600 kilos = 12 centners. A stacked cubic meter is termed *Raummeter* or *Stère*.

Section V.—Hardness.

The **hardness** of a body is its power of resisting the insertion of another body into its mass. Woods which offer considerable resistance to being worked by instruments are termed **hardwoods**, and others which may be easily worked are termed **softwoods.**

Owing to the non-homogeneous character of wood, it is clear that the resistance offered to working depends on whether the instrument used is acting parallel to the direction of the fibres, directly across them, or in a direction intermediate to these two. Resistance parallel to the fibres is connected with the **fissibility** of wood, which will be discussed further on. The resistance which wood offers to instruments also varies with the kind and mode of working of each instrument. If other factors are considered which influence the relative hardness of wood in different cases, it becomes evident that this property of wood is not nearly so easily estimated as might at first sight be imagined.

The factors on which the hardness of a wood depends are :—its **anatomical structure**, the **coherence of its fibres**, the **amount of resin** it contains, its degree of **moisture**, and the **kind of instrument used.**

1. *Anatomical Structure.*

The more ligneous substance any wood contains the greater will be the resistance it affords to instruments; its hardness is therefore proportional to its specific gravity, and heavy woods are harder than light woods.

2. *Coherence.*

A firm coherence of the woody fibres as opposed to loose texture will evidently increase the hardness of a wood. Medullary rays are of considerable influence here, but observation has not yet decided, whether the coherence of the ligneous linings of cell walls with the primary wall common to two contiguous cells is of importance in this respect, and whether it varies for different kinds of wood. The course of the fibres being straight, curved or twisting, has certainly, however, some influence on their coherence.

3. *Resin.**

Coniferous woods become harder the more resin they contain, especially when this fact is combined with narrow annual zones of wood. Resin also increases the hardness of a wood the more, the less turpentine it contains, *i.e.* the harder it is in itself [thus Weymouth-pine containing much turpentine but little rosin is, especially when dried, a very soft wood.—Tr.] All this explains the great hardness of knots in larch and spruce planks, for these knots are very narrow-ringed, and highly resinous.

[Oil applied to cricket-bats increases their toughness and resistance to blows, and should be re-applied when dried.—Tr.]

4. *Degrees of Moisture.*

Dry wood is harder than green wood, a fact which may be partly explained by the softening of the fibres by water, and partly by the swelling of wet wood. Heavy woods gain most in this respect, and it is well known that beech, oak and sycamore wood is much easier to carve, hew and saw when green than when dry. Pliability also results from moistening wood; wood-fibres in this condition bend before the intrusive edge of an instrument, without being torn, and close-in towards the neighbouring fibres, thus rendering the wood locally denser for the time being. Porous woods, such as black poplar, aspen, willows, &c. chiefly share in this peculiarity, for their wood affords the largest spaces into which the fibres can be compressed. This pliability of the fibres is chiefly noticed at right angles to their greatest length, or transversely.

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* [Resin is a mixture of oil of turpentine and rosin.—Tr.]

As a rule, in case there be no great difference in density between heartwood and sapwood, the heartwood, imperfect heartwood and older parts of trees, owing to their comparative dryness, are harder than the corresponding sapwood and the younger parts of the tree. This is the case only when the wood is sound, for even a beginning of decay in old trees will render the heartwood soft.

5. *Action of Instruments.*

It is chiefly iron or steel instruments which have to penetrate the substance of wood, and their shape and action on wood is very variable, as may be seen from the following list:—auger, file, plane, saw, chisel, knife, graving-tool, polishing-stone, &c. No proof is needed to show that the resistance wood offers to a tool varies considerably according to the kind of tool used. It is often, for instance, difficult to drive a nail into a narrow-zoned larch post which has stood long exposed to wind and rain, but which can be easily sawn in two. In order then to know the hardness of wood in all directions, it must be considered with reference to its resistance to the instrument used. It is therefore impossible to distinguish wood by absolute degrees of hardness. The forester is chiefly concerned with its resistance to the axe, saw, pruning knife and bill-hook.

(a) **The resistance a wood offers to the axe** varies with the direction in which the wood is attacked, and is greatest perpendicular to its fibres and least in the plane of the medullary rays. By hardness in this case is understood the resistance the fibres offer to a cut with the axe more or less at right angles to them. The density of the wood, the pliability of its fibres and its degree of moisture will influence matters. It is evident, however, that softwoods with pliable fibres require heavier axes than heavy short-fibred wood. For in order to get the better of the bending and yielding of the fibres in the former case, the axe must act with a greater weight, as its action in this case is not only cutting, but also rending.

In the case of heavy compact wood the fibres do not bend, and the axe cuts more freely and may be therefore lighter than in the former case, but must have a thinner, finer and harder steel edge.

In order to reduce the resistance offered by wood-fibres to the axe at right angles to the blade, it is usual to cut obliquely; the more obliquely the cut is delivered the greater is the approach to a splitting action, when resistance is least and the work to be done is consequently reduced.

Experience shows that to fell frozen wood comparatively heavy axes are required, but the reason for this is not clear.

(b) **The resistance wood offers to the saw** is very different from that it offers to the axe. The direction in which the saw acts is not nearly so important as in the case of the axe: it appears on the contrary in the case of most woods, and especially that of light softwoods, that the resistance to the saw is greater parallel to the direction of the axis of the tree, than across the fibres; the saw never splits, but tears and cuts the fibres asunder, and sometimes separates them from one another with a plane-like action.

In the case of broad-leaved trees the softer and longer the fibres, and the looser the texture of the wood, the greater is the difficulty of working the saw; in such cases the teeth do not divide the fibres, but tear them from neighbouring fibres, the section becomes rough and uneven and a large quantity of sawdust is produced, all this indicating difficulty in the work. Sawing becomes easier in the case of dense short-fibred wood with coherent fibres, and smooth cuts with little sawdust result. It is therefore easier to saw heavy than light broad-leaved wood. Conifers are sawn most easily of all woods, owing to their simple anatomical structure and fine medullary rays.

Moisture diminishes the hardness of wood, so that it is easier to saw green wood than dry wood, but at the same time, moisture increases the pliability of the fibres; in the case of heavy woods, this increase of pliability is not important, and for most conifers does not appear to counterbalance the advantage of the softness of the moist fibres. Hence, Scotch pine, larch and spruce woods are more easily sawn green than dry; but in the case of certain soft-fibred loosely textured woods, the pliability of the fibres counterbalances the advantage of moisture, as for instance in black poplar, aspen, birch, willow, &c., the timber of which is generally easier to saw dry than green.

If we take the resistance to the saw across the fibres offered by beechwood as 1, Gayer's own experiments in the case of freshly felled wood give the following results:—

	Resistance to saw.
Silver-fir, spruce and Scotch pine	=0·50—0·60
Maple, larch, alder	=0·75—0·90
Oak	=1·03
Sallow, aspen and birch	=1·30—1·40
Lime, willow and poplar	=1·80

(c) **Resistance to Pressure and Friction.**—In many cases consideration arises as to the resistance wood offers to pressure and friction, and against thrusts and blows; it needs no discussion to show that heavy woods resist these actions better than light woods.

The knife hardly deserves mention as a forest tool, but, when used with the hand, its action unites that of the axe and saw more than that of any other tool; it affords, therefore, a suitable test for approximately classifying the degrees of hardness of woods.

Nördlinger, from average results obtained with different tools, gives the following classification of woods according to their hardness:—

Hard as bone: Barberry, box, privet, lilac.

Very hard: Common dogwood (*Cornus sanguinea*, L.), yellow dogwood (*C. Mas*, L.), whitethorn, blackthorn.

Hard: Robinia, field-maple, sycamore, hornbeam, wild cherry, service-tree, buckthorn, elder, yew, pedunculate oak, mahogany.

Fairly hard: Ash, holly, mulberry, mountain-pine, plane, quince, Turkey-oak, elm, beech, sessile oak, [sweet-chestnut, Tr.].

Soft: Spruce, silver-fir, horse-chestnut, black alder, white alder, birch, hazel, juniper, larch, black pine, Scotch pine, bird-cherry, sallow.

Very soft: Paulownia, Weymouth-pine, poplars, aspen, most willows, lime.

SECTION VI.—FISSIBILITY.

By the **fissibility of wood** is meant the property it possesses of being split by a wedge driven into it in the direction of the fibres.

Fissibility is clearly a form of hardness; wood is not merely affected by the actual contact of a wedge, for the fibres separate from one another in front of the wedge, and the ease with which this happens is a measure of the fissibility of the wood. **Resistance to fission** is the opposition wood offers to the passage through it of a wedge. Fissibility is chiefly affected by the structure of the wood in question, and also, to a certain extent, by the elasticity of its fibres; other factors which must not be overlooked intervene in varying degrees.

1. *Structure of the Wood.*

Straight and long fibres render a wood fissile, and this is the case with most conifers and all rapidly-growing woods. Freedom of a stem from branches and knots is another important condition for fissibility, and this should be the case from the earliest years of the tree's life.

A wavy or twisted, unhomogeneous condition of the fibres, owing to knots, wounds, bent fibres, or dormant buds, implies considerable power of resisting fission. Thus, it is difficult to split the wood of elms, birch, planes and most maples; also of slowly-grown trees of other species, or those which have grown in a roomy condition, from wide planting, such as branchy spruce. Branch and rootwood, owing to twisted, knotty structure, is harder to split than stemwood, and no part of a tree is harder to split than the stump, where the tap- and side-roots unite to form the bole. Trees with twisted fibre are specially hard to split, and it is found that those twisting from left to right (against the sun's apparent course) are harder to split than those twisting in the opposite direction.

The structure of the medullary rays has very great influence on the fissibility of a wood, for they are in the plane in which the principal splitting action lies, so that oaks and beech, which have large rays, are easily split. Conifers possess extremely small but very numerous medullary rays, which are also very fine, consisting usually of only one row of cells; this is also the case with poplars, willows, alders, birch, limes, hazel, &c. Thus, in such cases, the longitudinal fibres lie straighter between these numerous fine rays than they do between larger ones, and the wood is easily split.

The coherence of woody fibres in this case means chiefly that of the longitudinal fibres to the medullary rays, which in some species appears to be considerable, as, for instance, in the cork-oak, elms, hornbeam, sycamore and other maples. In most woods, however, this coherence is slight. The coherence between the annual woody zones is greater, and this is probably due to the fact that most medullary rays run uniformly through a number of annual zones of wood binding them together and thus increasing their mutual coherence. **It is, therefore, easier to split wood radially than tangentially.** Fission along annual zones is easiest in conifers, poplars and aspen.

2. *Elasticity and Flexibility of Fibre.*

Elasticity always increases fissibility, for the more elastic a wood, the faster the splitting precedes the wedge, and the wider the cleft opened in the wood. Elasticity of fibres varies with their length and straightness, advantages peculiar amongst others to conifers. In the absence of elasticity, either **brittleness** occurs, as in short-fibred woods, or **flexibility**, as in the case of many soft broad-leaved species; in the former case, a splitting action breaks the fibres; in the latter, they yield before the wedge without transmitting the shock any further.

3. *Moisture, &c.*

Wood splits best when either **green** or **quite dry**; half-dried wood is least fissile. This is due, when the wood is green, to the flexibility of the fibres, and when it is quite dry, to their elasticity.

Frost sometimes nullifies the fissibility of wood by reducing the elasticity of the fibres. Frozen wood is brittle, and the difficulty of splitting it is further increased by the fact that the wedge will not bite and falls out of the cleft. **Resin** also increases the difficulty of splitting wood, as is easily seen in the case of the lower resinous parts of Scotch pine-trees.

4. *Locality and Mode of Growth.*

The effect of the locality and mode of growth on the fissibility of wood is considerable. Close growth and moist soil favour height-growth, straightness, length of fibres and freedom from branches and knots ; producing straight and clean-grained wood, which is easy to split.

All poles grown in a dense wood and fast-grown coppice-shoots of almost any species split easily, showing the favourable effects on fissibility of quick-growing crowded woods. Other factors being equal, that part of a tree which has grown most rapidly will split most easily, and this is most generally the case with the upper part of a stem.

5. *Concluding Remarks.*

Fissibility is an important property of wood, for a number of wood-manufactures depend on it and upon the convertibility of trees into wood-fuel, which is much more readily and cheaply effected with fissile wood, such as that of conifers, than with tough sycamore or hornbeam.

A forester may easily detect the comparative fissibility of the wood of a tree from its outward appearance. Considerable length of stem, a clean bole, a uniformly and gently-tapering stem, fine clefts in the bark (especially in oak, Scotch pine and other trees with **rhytidome**, or coarse, dead bark), long and straight bark-cracks, are all indices of fissibility of the wood in a tree. The locality is also a certain index to an expert, and so is a slight amount of heart-shake, visible on the section of a felled tree. During the felling of very fissile trees, after the stump has been half severed, the tree may split with its own weight; this frequently happens to tall beech-poles grown in a crowded wood.

The following list of trees is arranged in their order of fissibility, but it should be noted that this is less dependent on the species than on the individual growth of trees:—

Very easy to split: Spruce, silver-fir, Weymouth-pine, Scotch pine, larch, alder.

Easy to split: Oaks, sweet-chestnut, beech, ash, Cembran pine.

Difficult to split: Common maple, hornbeam, elms, sallow, birch, sycamore, poplar, mountain-pine, lime, black pine.

SECTION VII.—PLIABILITY.

1. *General Account.*

Pliability is that property of material owing to which it may undergo changes of shape without fracture.

Wood possesses this property in a high degree, and it gives rise to many wood-industries. In order that wood may be pliable, a certain power of extension must be possessed by its fibres, which is chiefly the case in long and straight-fibred wood, but not in wood with short or crooked fibres. The presence of knots, wounds which have been occluded, burrs or wavy wood, defects due to decay, &c., may nullify the pliability of a wood. Woods which are not pliable are termed **brittle**.

Wood which is pliable may be either **elastic**, or merely **flexible**. When a pliable piece of wood has been subjected to a force—for instance, has been bent—and resumes its former shape, as soon as that force ceases to act, it is said to be elastic. The action of the force, however, must not be great enough to exceed the limit of elasticity, for then the form of the piece of wood will be permanently changed, and the other kind of pliability arises termed **flexibility**. If the limit of flexibility be exceeded for any piece of wood, a fracture will ensue. Every wood possesses both elasticity and flexibility, but the latter property generally exceeds the former; a wood may, therefore, be termed **flexible** when its elasticity is almost insignificant, and **elastic**, when the limits of its elasticity nearly approach those of its flexibility.

The pliability of a piece of wood is not constant under different circumstances, but may be favoured under certain conditions in different degrees. The most important of these is the degree of **moisture** in the wood. Dryness makes a wood elastic, but may altogether nullify its flexibility. Damp and heat combined render a wood very flexible, but never increase its elasticity ; so, when completely saturated with water, the elasticity of a wood is quite thrown into the background by the surprising increase of its flexibility. Basket-work by means of finely-split ribbons of wood of aspens, sallows and spruce, is an example of this treatment.

Another factor is the **resin** of conifers. According to Nördlinger, a certain amount of resin, as it occurs in the heartwood of Scotch pine and larch, increases the elasticity of a wood, while too much resin renders a wood brittle.

Frost reduces both the elasticity and flexibility of wood. Girdling living trees and allowing them to die standing increases the flexibility of their wood.

Much more observation is required before a satisfactory detailed knowledge of the elasticity and flexibility of woods has been acquired, scientific observation having hitherto established certain facts regarding these properties which are quite at variance with popular ideas of the subject. The question will now be dealt with separately under the headings elasticity and flexibility.

2. *Elasticity.*

Two factors appear to be chiefly influential in determining the elasticity of a wood. They are its **specific gravity** and **anatomical structure**. The heaviest European woods are usually the most elastic—as, for instance, yew, robinia, oak, sycamore and ash ; for the elastic masts of ships, only narrow-ringed, heavy Scotch pine-wood is suitable. The heavier stemwood of trees is more elastic than the lighter rootwood.

As regards **anatomical structure**, even grain (uniformly-sized fibres), long and parallel wood-fibres, and freedom from branches, knots and other abnormities, increase the elasticity of a wood. This explains the elasticity of certain woods with low specific gravity, as, for instance, spruce, silver-fir, larch, Scotch pine and lime-wood. These woods also, when narrow-zoned, and consequently heavier, are more elastic than when more rapidly grown and consequently softer.

Sprucewood is generally used for sounding-boards to musical instruments, and the best kind for this purpose is finely ringed wood grown on medium soil at altitudes of 2,000 to 4,000 feet above sea-level. The properties of this wood for sounding musical notes consist not only in its high elasticity, but also in its uniform texture, causing equable vibrations throughout the wood, which therefore gives out pure musical notes.

The value of the timber of our forest trees is greatly influenced by its elasticity, as in cart- and carriage-building, planks and beams, wood used for implements, &c.; since elasticity depends on the density and clean growth of the timber, this gives a clear indication of what the forester should produce. In treating his woods he should follow all cultural rules which will increase these valuable properties of timber.

In the case of individual woods, owing to the varying circumstances which affect their elasticity and the little experimental knowledge already attained in this respect, it is very difficult to classify them according to their elasticity; all that can be done is to separate them into two classes from the results of Nördlinger's investigations :—

Very elastic: Yew, larch, spruce, Scotch pine, silver-fir, robinia, oak, Spanish chestnut, ash, hickory, sycamore, Weymouth-pine, lime.

Less elastic: Poplar, Cembran pine, beech, juniper, aspen, birch, alder, black pine, elm, walnut.

3. *Flexibility.*

It has been already stated that the quality of flexibility of a wood is rarely combined with elasticity. Whilst to secure the latter the wood should be as dry as possible, a damp or half dried condition renders a wood more flexible, and only in such a condition can economic advantage be taken of the flexibility of a wood. It is also necessary that a piece of wood be of moderate transverse dimensions if considerable change of form is desired. A complete saturation of wood frequently nullifies its elasticity, keeps its brittleness far in the background and therefore considerably increases its flexibility. Steaming wood is the best method for this purpose, there being hardly any species of wood which cannot be thus rendered flexible.

As a rule, the highest degree of flexibility is found in the case of softwoods as opposed to hardwoods. This is chiefly owing to the length and straightness of their fibres, and to the large lumina of their cells and fibres which give more play for bending than in hard woods. Hence, root-wood is more flexible than stem-wood, and the latter more flexible than brittle branch-wood, except in the case of the flexible branches of birch, spruce, and some other species.

The age of the wood also has an influence on its flexibility, as young wood, and especially sapwood, is in many species more flexible than old wood, the heartwood of many old trees having very little flexibility. Wet soil in the case of oaks, beech, and other species produces brittle wood. Resin increases the flexibility of woods.

The most flexible woods are the young stool-shoots of willows, birch, hornbeam, aspen, ash, oaks, elms, &c., and branches of birch and spruce; young roots of Scotch pine and also of spruce, grown in poor, sandy soil, where they attain a considerable length, possess great flexibility. The following woods are considered naturally flexible: birch, mountain-ash, willows, poplars, cork-elm, hickory, species of *Sorbus*, saplings of oak, hazel, and suppressed spruce, &c.

Flexibility is a necessary quality for wood in many industries, such as for sieve- and drum-frames, staves, hoops for casks, basket-work and withes for binding faggots or rafts of floating wood; the cartwright also requires long-fibred, flexible wood for shafts.

Steaming is largely applied to wood by shipbuilders in casing the curved parts of ships, when steamed planks are nailed on damp and hot. Similarly, curved planks are used in carriage building.

Bent-wood furniture is also made from steamed or boiled beechwood, and steamed split pieces of ash and oak are twisted round cylinders into spiral-shaped banisters for staircases. The curved pieces of wood in violins and other stringed instruments are all steamed. These industries show what a large amount of pliability even hardwoods may possess when steamed.

Withes are softened in the fire, or even in ovens used for the purpose, before being twisted.

Wood which has been steamed and bent retains its new shape permanently when thoroughly dry. This may be seen in the case of cask-staves, and other curved pieces. Thoroughly dried steamed wood, and also injected wood, has lost all flexibility and is very brittle.

SECTION VIII.—STRENGTH OF TIMBER.

1. *General Account.*

By the strength of timber is meant the resistance it offers to the separation of the fibres of which it is composed. Separation may be due to tensile, crushing, twisting, shearing, and bending actions.

The ultimate strength of timber is measured by the force in lbs. per square inch of section which must be exerted in order to break it.

In countries using the metric system the unit is a kilogram per square centimeter, and since the atmospheric pressure on one square centimeter is very nearly one kilogram, the breaking force is frequently expressed in atmospheric pressures (at.).

[The elastic strength, or load which may be borne without causing permanent deformation, is about one half the ultimate strength ; the working load to which it would be wise to subject wood being only about one tenth of the ultimate strength. This large factor of safety is advisable in order to provide for the following contingencies :—

Possibility of unsoundness in the timber ;

Provision against deterioration ;

Allowance for extraneous forces not taken into account in the calculation ;

To give a capability of resisting the extra transient effect due to the abrupt application of a load.

The effect of the sudden application of a load in causing strains, such as would approximately be due to a fast moving train running on a bridge, is twice that due to the same load applied gradually.

A load repeatedly removed and reapplied is called a **live load,** as distinguished from the so-called **dead load** due to the weight of the structure itself, which is applied once for all. The liability of the sudden application of a live load requires that the factor of safety should be twice that for a dead load, and if there is a possibility of the load being applied by impact, or reversed in direction, the factor should be greater.—TR.]

The different kinds of strength in timber will now be considered first, then the factors which modify them, as far as these are known, and finally the comparative strength of the different woods.

The following kinds of strength will be discussed seriatim :—**tenacity, and resistance to crushing, torsion, shearing** and **transverse straining actions.**

2. *Tenacity.*

The tenacity of all wood is greatest along its grain, attaining 1,500 atmospheres and more, but may also sink as low as one-fifth or one-sixth of this amount. Bauschinger's experiments made in 1882, in the laboratory of the Engineering College at Munich, appear to prove that this form of strength is proportional to the specific gravity of the wood : it is, however, rare for wood to be exposed to considerable tension, on account of the difficulty of getting secure attachments to the ends of the piece. In contrast with iron, fracture of wood by tension acts suddenly, there being only a very small amount of extensibility along its fibres.

3. *Resistance to Crushing.*

This is opposite to the resistance offered to tension, but also along the grain of the wood, and comes into play when wood is used for vertical piles, posts, wheel-spokes, and so on. Resistance of coniferous wood to crushing is 150—300 atmospheres. It also appears to be proportional to the specific gravity of wood. Overweighted pillars bend and break transversely.

4. *Resistance to Torsion.*

This is the resistance offered by the fibres of a fixed piece of wood to a couple of forces tending to twist one end relatively to the other. The windlass is about the only case in which torsion has to be resisted, and the dimensions of wooden windlasses (as for wells) usually provide a large margin for safety.

Resistance to Shearing.

This is a measure of the strength which resists the separation of the fibres sideways from one another.

Wood shows the least strength of all in resisting shearing, according to Fischer it is only 44 atmospheres. Beechwood is said to possess the greatest strength of this description among European woods.

6. *Transverse Strength.*

(a) **General Account.**—Transverse strength is the most important of all, and is requisite to resist the fracture by bending of beams, joists, rafters, ladder steps, axle-trees, &c. It measures the resistance which wood offers to breakage by a force acting at right angles to its grain, and is the result of a combination of a resistance to tension and to crushing. The transverse strength of certain woods may be double, and even more than double, that of others. The demands on the transverse strength of wood for building purposes are most economically met by placing the timber so that the greater transverse dimension is in the plane of bending. When great transverse strength is required, iron or steel may be substituted for wood.

As regards the factors which affect the greater or less transverse strength of wood, the following are the most interesting, the results being taken from Bauschinger's and Tetmajer's experiments. In the first place, it is clear that thorough soundness of timber is an essential condition of its strength.

(b) **Anatomical Structure.**—Straight-grained wood, free from any defect, possesses comparatively high transverse strength; knotty wood, and wood containing resinous concretions, occluded wounds, or other defects, is weak, and wood with wavy or twisted fibre, according to Nördlinger, often possesses only two-thirds of the transverse strength of straight-grained wood, otherwise similar to it.

(c) **Specific Gravity.**—The specific gravity of a wood is also of great importance in determining its transverse strength, but only in comparing woods of one species. Wood which is highly resinous is brittle, and hence that of the black pine is deficient in transverse strength as compared with that of many other conifers.

(d) **Locality.**—As regards the influence of the locality in which the tree has been grown, Tetmajer's experiments show that the woods of silver-fir, spruce and larch grown on cold aspects are stronger than when grown on warm aspects; also that spruce-wood is stronger when grown above 1,300 metres (4,225 feet), and silver-fir wood below that altitude. The larch in the Bavarian Alps, according to Bauschinger, resembles the silver-fir in this respect. In different trees individuality is a most important factor of strength, as of all the economic qualities of timber.

It is customary to rate wood felled in December as strongest and that felled in March to have lost one-third of its strength, but such assertions should be accepted with caution.

(d) **Comparative Strength of Different Species of Wood.**—Authorities still differ as regards the comparative strength of the different woody species.

Bauschinger classes conifers grown in Upper Bavaria as follows:—

	Atmospheres.
Transverse strength of larch . . .	545—745
,, ,, spruce . . .	365—690
,, ,, Scotch pine . .	245—705
,, ,, silver-fir . . .	485—570
,, ,, Cembran pine .	365
,, ,, Weymouth-pine .	250—290

It should be noted that the Scotch pine was least at home in the locality.

[Tredgold* places the broad-leaved trees in the following descending order of transverse strength:—

Oak.
Ash.
Beech.
Robinia.
White Poplar.
Common Elm.
Sycamore.
Alder.
Birch.
Sweet Chestnut.
Black Poplar.
Willow.—Tr.]

Builders practically assign the greatest transverse strength to oak, then to the indigenous conifers, and then to ash. Beech, birch and alder, are considered by them as weak timbers. In order to produce strong building-timber, the same rules must be followed which have been already laid-down under the head of elasticity.

SECTION IX.—RELATIONS OF WOOD TO WATER.

Wood is rarely used so that it will not be exposed to moisture in some form or other, and hence the effects of water on wood are important to the forester. The subject will be considered below as regards the **drying or seasoning of wood**, its **power of absorbing water**, and the **changes of shape in wood** owing to these two processes.

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* Tredgold's Carpentry by Hurst, 1871.

1. *Seasoning of Wood.*

Wood must generally become air-dry before it can be utilized. The quantity of water which wood contains has been already shown to vary according to the season of the year, the part of the tree from which the wood has been taken, and the species of tree. Wood loses its water chiefly by evaporation, the factors influencing the degree of dryness which it can attain being its anatomical structure, its contained resin, the amount of surface of the wood exposed to the air and the degree of dryness of the air.

(a) **Anatomical Structure.**—All wood parts with its water most readily along the grain, and most slowly parallel to the medullary rays; hence transverse sections of wood become dry soonest. Porous wood dries sooner than close-grained wood.

The rate of drying for the different species of trees is not yet satisfactorily established, but it appears that rapidity of drying is not directly affected by the anatomical structure of wood, and that for practical purposes the following statements hold good:—

Sapwood dries easier than heartwood or semi-heartwood, at least as long as the log is in the round.

Logs of silver-fir, under similar conditions, dry more slowly than spruce logs of like dimensions, and beechwood dries more quickly and thoroughly than elmwood.

Hartig gives the following percentages, by volume, of water in green wood of the following species:—

Birch	44·3	Spruce	40·5
Oak	43·7	Scotch pine	38·3
Beech	42·6	Larch	27·5

When air-dry—

Birch	8·8	Spruce	11·5
Oak	11·5	Scotch pine	12·1
Beech	12·3	Larch	15·0

Thus water is more mobile in broad-leaved trees than in conifers, owing to the differences in the structure of their wood, and especially to the position of the fibres with bordered pits. The presence of resin in coniferous wood (Scotch pine and larch) also causes it to retain more water when air-dried than broad-leaved woods.

(b) **Extent of Surface exposed.**—The rapidity of drying is clearly proportional to the extent of woody surface exposed, and it is clear that barked wood dries more rapidly than unbarked wood. According to Roth, split and unsplit Scotch pine firewood retain water in the ratio of 8·3 : 100, so that split wood dries up 12 times faster, the surface exposed of the split wood being 11 times greater than that of the unsplit.

As planks expose more surface to the air than other forms of converted timber, they dry most readily.

(c) **Humidity of the Air.**—The humidity of the air varies greatly, according to locality and season, and hence it is clear that the effects of winter- or summer-felling on the drying of timber must be considerable. Good ventilation is also very important, and wood which is required to dry rapidly should be placed in breezy places. Wood while drying should not be in contact with the ground, from which it may absorb moisture.

(d) **Mode of Seasoning Wood.**—Wood intended for use may be either dried naturally in the air, or artificially.

Drying logs in the air is a slow process, which may take two or more years.

Wood in the round is frequently split in half or quartered, or converted into planks and scantling, in order to hasten the drying process ; firewood should be split. All wood intended to be seasoned should be raised above the ground, to allow the air to pass beneath it, and converted wood should be sheltered from the rain and sun, but not so as to exclude the wind.

Timber in the round will not, a year after felling, have lost much moisture as compared with its green state, and only after three or four years can it be considered seasoned. Floated timber, when landed and exposed on all sides to the air, dries more rapidly. Rainwater has not much influence on wood which has been thoroughly dried.

Several systems of drying-chambers are in vogue, and hardly any large industrial wood-establishments dispense with them, thus effecting their purpose in a few weeks' time. As a rule, they are built of masonry, and heated by steam-pipes to temperatures between 50° and 80° C. (112° to 176° Fahr.), whilst powerful exhausters pump-out the air which has been rendered moist by the timber and pump-in heated dry air. Large logs on trucks are passed into such chambers on rails, and the hot-water pipes run between the rails, whilst there are cold-water pipes in the walls to cause a rapid circulation of the air.

In England the principle of drying wood by currents of air only slightly heated, but driven rapidly by revolving fans, is often followed.

The finer woods may be dried by packing in common salt, which is highly hygroscopic, in air-tight chambers. René, a pianoforte manufacturer at Stettin, in order to season his wood, thoroughly exposed it in an air-tight chamber to ozonized oxygen. This apparently oxidizes the contents of the sap, and in 12 to 24 hours renders the wood as thoroughly seasoned as if it had stood for years in the air.

2. *Absorption of Water by Wood.*

A wood which dries quickly and thoroughly also absorbs water again in the same degree, so that the more porous and less resinous a wood is, the greater its exposed surface and the damper the medium into which it is brought, the more readily does it absorb water. Decaying wood absorbs water readily, air-dried wood absorbs water much more slowly, and wood which has been steamed is far less absorptive of water than unsteamed wood. For an account of the absorption of preservative substances by injection, the reader is referred to the third part of this book.

Whilst in most of the industrial uses of wood, rapid withdrawal of water is required, there are some in which wood should be as watertight as possible. This is especially the case with staves for casks, which should part with as little of their contents as possible. As already stated, the direction perpendicular to the medullary rays is that through which liquids pass least freely. The fact that oak-staves are split along the radius of the stem, and that the medullary rays are therefore parallel to their longer surfaces, renders them very impervious to liquids contained in the casks.

Certain kinds of oakwood, however, both broad and narrow-zoned, of coarse structure, are permeable to liquids, and casks made of them will leak. Beechwood is very permeable, and is, therefore, useless for wine- and beer-casks. Experience is said to have proved that wood felled in December is less permeable by liquids than wood felled in the spring.

3. *Results of the Relations of Wood to Water.*

Air-dried wood is subject to variations in the quantity of water it holds, according to the condition of the atmosphere or of the media with which it is in contact. The results of these changes are an increase in bulk in the wood when water is absorbed, and a decrease in its bulk when it parts with water. This phenomenon is of the greatest importance among the economic qualities of wood, and the wood is then said to **shrink and swell**, or both actions are described as **warping**. They are explained by the power the cell-wall possesses of imbibing liquids: when water is imbibed, the *mycellæ* of the cell-wall are forced apart, and the wood swells; when the wood parts with water, the *mycellæ* come closer together, and the wood shrinks.

(a) **Shrinkage of Dried Wood.**—The loss of water by wood is a measure of the amount of its shrinkage, and this therefore varies greatly with green, half-dried or air-dried wood. As wood cannot begin to shrink until it has lost all water from the lumina of its cells and tracheæ, and this only takes place after the walls of these organs have begun to part with water, the total amount of shrinkage will about be the same for both spring- and summer-wood, though the former dries and therefore shrinks more rapidly than the latter. Sapwood of most woods and especially of oak shrinks more than heartwood and semi-heartwood.

The amount of shrinkage in different woods is not proportional to their specific gravity. It may be said in general, that heavy close-grained woods shrink more than light woods, and most broad-leaved woods shrink more than conifers; but there are exceptions to this rule, as may be readily imagined from the great variability in the specific gravity of woods. It may, however, be confidently asserted for any species that the heaviest wood shrinks most.

Nördlinger gives the following account of shrinkage by volume of air-dried woods :—

Most shrinkage (5 to 8 per cent. of the green wood): walnut, lime, beech, hornbeam, elm, sweet chestnut, wild-cherry, Turkey oak, birch, alder (?), apple.

Moderate shrinkage (3 to 5 per cent. of the green wood): Maple and sycamore, black pine, Scotch pine, poplar, yew, horse-chestnut, ash, aspen, oak, robinia.

Least shrinkage (2 to 3 per cent. of the green wood): Weymouth-pine, spruce, larch, silver-fir.

R. Hartig gives the following shrinkage for air-dried wood :—

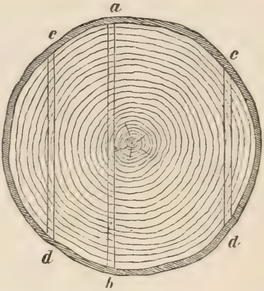
Beech . . .	13·5	per cent. of green wood.
Birch . . .	13·2	,, ,,
Oak . . .	12·2	,, ,,
Spruce . . .	8	,, ,,
Larch . . .	8	,, ,,
Scotch pine . .	7·7	,, ,,

The narrow-ringed porous wood of the sessile oak does not shrink so much as the broad-ringed heavy wood of the pedunculate oak, and the former is therefore more suitable for furniture, machine-frames, &c. than the latter.

Narrow-ringed sprucewood from the Alps shrinks much less than the softer sprucewood from lower levels, and the same holds good for larchwood. The more resinous a wood, the less it shrinks (Mayr).

Wood shrinks unevenly when cut in different directions: it shrinks least along the grain, and for ordinary purposes this shrinkage may be neglected; it is more considerable and may extend to 5 per cent. of the radial length, along the medullary rays, and shrinkage is greatest and may attain 10 per cent. along the annual rings, *i.e.* the circumference of a log. Exner states that beechwood from the stem shrinks twice as much tangentially as radially, and that experience shows radial shrinkage to be 4 per cent. and tangential, 8 per cent. Thus in the case with planks, the central plank *a b* (fig. 5), falls almost in the radial direction, whilst the side-planks *c d*, are more tangential and therefore shrink much more than *a b*.* A floor made of planks like *c d*, which are not thoroughly seasoned, will soon show wide gaps between the planks.

Fig. 5.



(b) **Cracks in Dried Wood.**—If wood were a homogeneous substance, and its shrinkage uniform in all directions, only a reduction of volume would follow. As, however, wood shrinks unequally in different directions, and varies in structure in its different parts, the amount of shrinkage is quite irregular and the wood becomes distorted when it warps, and thus cracks and crevices appear in round wood. As shrinkage is greatest tangentially these cracks are chiefly radial, which is also the easiest direction in which wood splits, and this fact increases its tendency to crack radially.

The more rapidly a wood shrinks the greater is its tendency to crack. Wood felled during summer therefore cracks more than winter-felled wood, and completely peeled wood cracks more freely than wood on which strips of bark still remain, as is the case with wood barked during winter. The greater the amount of shrinkage of which a wood is susceptible, the more exposed it is to crack; thus, large pieces crack more than smaller ones, especially large transverse sections of wood and barked round logs, in which wide cracks are formed.

Split and quartered beams crack much less; still less, broad beams, planks and scantling, in which cracks occur only at the ends; least of all, veneer, which cabinet-makers therefore prefer to be as fine as possible.

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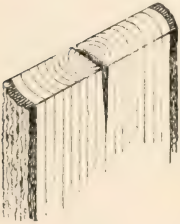
* [Planks for flooring should be laid with the inner layers of wood against the beams which support them, as when laid otherwise, the central part of the plank is liable to shell-out and impair the evenness of the surface. (Laslett's Timber and Timber Trees.)—Tr.

Unevenly grained wood cracks more than wood which is even grained, wood with broad summer-zones more than wood in which the summer-zones are narrow. Sounding-wood for musical instruments hardly cracks at all.

As a rule, the cracks formed during shrinkage are pretty straight: they are rarely zigzag, as in old silver-fir wood, being partly radial and partly tangential along the annual rings; this is also the case in old sprucewood from very high altitudes.

Wood which is badly cracked owing to shrinkage may become unsuitable for certain purposes. Cracks cannot be altogether prevented, but by **slow drying** may become inconsiderable. This may be effected by gradual barking, the bark being removed in strips, best of all in spirals, or the bark may be left for one yard at either end of the log and in its middle, and the rest barked. The best method is to convert the wood into planks and scantling while still green, and to dry these pieces slowly. Wood thus treated forms numerous small cracks, but no large ones rendering it more or less useless.

FIG. 6.



(After Boppe.)

In converting timber, the trunk should be freed from sapwood and also from its central part, which is specially liable to crack (fig. 6), by cutting it in halves or quarters. These pieces when air-dried may be converted into planks. The conversion should follow the radial direction as much as possible, in order to prevent cracks. When wood is used for water-pipes it must not be allowed to crack, and the best way to secure this object is to bore it while green, and use it at once; or if intended for future use, to keep it under water till required. Turners keep their freshly cut wood at first in cellars; later, in shady court-yards, and finally, in airy dry lofts. Experience has often shown that beech-trees felled in spring and left lying over summer with their crowns on, and thus drying gradually, hardly crack at all.

In order to prevent cracks at the ends of beams, planks and other scantling, small pieces of wood may be nailed on to them, or S-shaped iron clamps driven into the wood; tar, oil, grease, &c., may be smeared on their ends to fill the pores, or thick paper glued on them to keep off the effects of sun and wind.

When freshly sawn beech planks are stacked, each plank should be separated from its neighbours by small pieces of wood. Valuable timber has been protected against cracks by barking the trees as they stand, binding the bark on the stems, and delaying the felling till the wood has dried. Steaming wood is one of the best preservatives against cracks, but it must then be very gradually dried. Soaking or boiling timber in supersaturated solutions of salt has often given good results in preventing cracks.

(c) **The Swelling of Dried Wood exposed to Moisture.**—The swelling of air-dried wood exposed to moisture does not follow a similar course to the shrinking of drying wood. At first it swells rapidly, and after a month or six weeks has resumed its volume when green; no further sensible increase in volume then occurs, but the wood continues to absorb water and increase in weight from one to three years, as the wood-vessels, which may have been filled with air when it was felled, become full of water. It is however evident, that woods which shrink greatly when dried will swell correspondingly when again saturated, and that the swelling is greatest tangentially, and least along the grain of the wood.

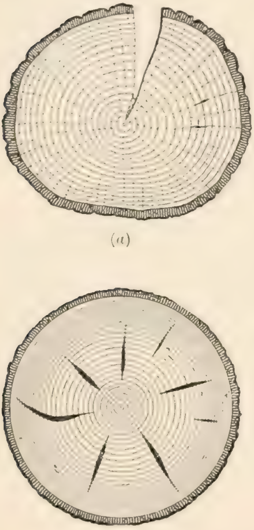
Although the extension of wood in length by the absorption of water is not considerable, R. Hildebrand, by observations made in Würzburg, has shown that it is greatest (1·52 per cent.) for walnutwood, 0·43 per cent. for oakwood, and is least for the wood of sycamore, beech, Scotch pine and spruce.

It is evident that in water logs will swell less rapidly than quartered or converted timber, especially if they still retain their bark, also that non-resinous coniferous wood and soft, broad-leaved wood swell more rapidly than highly resinous wood; these facts explain what kinds of wood are most liable to sink during floating operations. The great force exerted by swelling wood may be estimated from the fact that masons split large blocks of stone by drilling holes into them and inserting wedges of soft wood, which are then soaked with water.

[This method was formerly adopted largely in India for splitting slabs of granite and other stones in quarries.—Tr.]

(d) **Warping of Timber.**—Owing to the unequal contraction or swelling of different parts of wood due to changes in the hygroscopicity of the media to which it is exposed, it is said to warp; the extent of warping depends on the amount of shrinkage to which any wood may be subject.

Fig. 7.



(*a*)

(*b*)

(After Boppe.)

As a rule, hard, broad-leaved wood warps more than coniferous wood. Beech is most subject to warping, and walnut and mahogany warp considerably. Among conifers, larch and Weymouth pine warp least. Heart and semi-heartwood warp less than sapwood.

Whenever one side of a beam warps more than the other it becomes curved; planks are more subject to this the farther they are from the centre of the tree. Scantling lying on damp ground, and exposed above to the air and sun, bends upwards at the ends. Beams let into masonry, and panels of doors, flooring, &c., will warp during damp weather unless plenty of room is left for their expansion. All planks sawn out of twisted-fibred or wavy-fibred wood are also very subject to warping. [According to Boppe,[*] owing to the position of the largest annual zones, round logs from young trees warp as shown in fig. 7 (*a*), and older ones as in fig. 7 (*b*).—Tr.].

The measures taken in industries to prevent the warping of wood are, among others :—fitting together the object out of as many pieces as possible (either cut from different sections of the same wood, or from pieces of different species), as in billiard cues; steaming or boiling the wood; soaking it in turpentine, which fills its pores, and excludes water; allowing spaces for the expansion of pieces of wood, as in panel-work, door and window-frames, and where beams are let into masonry; wherever possible, isolating the wood from air- or soil-moisture, as in the case of wood-parquetry for floors, &c.

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[*] Technologie Forestière, p. 46.

Steaming wood is an excellent and long-approved method to prevent warping; makers of gun-stocks, artistic furniture, implements, &c., have long since adopted this practice. Steamed wood is said not to warp much, nor is it subject to be worm-eaten, while the wood becomes darker and better coloured. This method is especially employed with the wood of oak and beech. It has not yet been decided that this improved condition is due to the washing-out of reserve-material or hygroscopic salts from the wood, but there can be no doubt that the strength of the wood is not sensibly impaired.

The most frequent object of steaming wood is, however, to render it flexible; it can then be put to a number of uses, in which it undergoes great changes of shape.

SECTION X.—COLOUR AND TEXTURE OF WOOD.

Colour and texture are properties of wood which please the eye; they are subject to the whims of fashion, which give certain woods a local and temporary value in excess of others. Although the forester cannot produce at will woods with desirable colours and texture, yet he should have some knowledge of the peculiarities which give a high comparative value to certain varieties of wood. The industries which make the chief demands on the beauty of wood in grain or colour are those of the cabinet-maker, musical instrument maker, parquetry and wood-mosaic maker, carver, turner, &c.

1. *Colour of Wood.*

Healthy, freshly cut woods possess various colours :—

Yellowish white: Box, spruce, birch, silver-fir.

Bright yellow: Poplar, Scotch pine, Weymouth-pine.

Greyish yellow: Sycamore, ash, beech, hornbeam.

Brownish yellow: Oaks, mountain-elm.

Reddish: Alder, common elm, larch- and Scotch pine heartwood, Cembran pine.

Reddish brown: Mahogany, red cedar, and many Indian woods.

Golden brown: Teak.

Dark brown: Walnut.

Black: Ebony.

Some woods may have different shades of colour, as oak, which is either dark or light. This shading of colour in woods may be very marked, and caused by variations of soil and rate of growth, more or less perfect formation of heartwood, &c.

[In satin-wood, stripes of different shades (due to different directions of its grain) appear in the same wood; in marbled wood these shades have striking contrasts, as in Calamander-wood, a kind of ebony.—Tr.]

After wood has been kept for some time its colour usually deepens, and many bright-coloured woods become greyish. Spruce in dry situations retains its bright colour longer, whilst silver-fir soon becomes grey: on this account the wood of spruce is preferred to that of silver-fir for wainscots and floors.

Artificial colours are imparted to wood by acids, varnishes, stains, milk of lime, &c.

2. *Texture of Wood.*

The texture of planed wood depends on its anatomical structure, on the arrangement of its fibres, and the direction in which it has been sawn. Wood may be straight-grained, wavy, mottled, bird's-eyed, &c. The grain may be fine or coarse, the latter often owing to rapid growth. The former quality may usually be detected on the bark, as coarse-barked trees are usually coarse-grained. Wood is said to be **even-grained** when it possesses fine medullary rays, and not only equal annual zones, but narrow summer-zones, as in slow-growing sessile oak, spruce or silver-fir. Wood is also even-grained in the case of many fruit-trees, with evenly-distributed pores (pear, apple, cherry, service-tree, &c.).

[Also in ebony, in which all the pores are filled with a black substance,—and in box-wood, where the annual zones are very narrow, the wood-fibres have extremely small lumina and the small pores of the vessels are sparsely and evenly distributed.—Tr.]

Other wood is **uneven-grained** as in the case of coniferous wood with strongly developed summer-wood, and woods with large medullary rays. As regards the direction in which the wood is cut, the **silver-grain** occurs where the medullary rays are shown in their broadest section on radial cuts of oakwood, and the tangential cut shows the ends of the rays.

Fine-textured woods are those which show freedom from knots, fine or even grain, fine waviness, or other marks. As a rule, dense broad-leaved species are more finely textured than porous woods, and more easily polished. **Coarse-textured woods** are coarse-fibred, light, porous woods, those with a considerable difference between the spring- and summer-woods, and knotty wood. As already stated, fashion makes a great difference in the relative value of woods at different times.

SECTION XI.—DEFECTS AND UNSOUNDNESS IN TIMBER.

The study of the diseases of woody plants belongs to Vegetable Pathology and Forest Protection. Under Forest Utilization, only the fractures, defects and abnormities of wood will be considered which in any way permanently reduce the utility of wood.

Such defects of wood may be separated into two groups—those resulting from abnormities in the connection or structure of healthy wood-fibres, and those resulting from disease.

1. *Defects in Sound Wood.*

(a) **Heart-shake.**—Heart-shake consists of radial clefts in the timber proceeding from the pith and extending more or less towards the sapwood and up the stem. The defect is termed **star-shake** when there are several such clefts, and **simple heart-shake** when there is only one cleft extending in a line across the pith.

Heart-shakes of both kinds usually occur at the base of a tree, and are clearly seen on the stump left in the ground. They frequently, however, and especially in the case of simple heart-shake, extend through the whole stem and into the boughs, as frequently with aspen, and other poplars, elm, horse-chestnut.

Heart-shake is commoner in the case of large trees than with younger ones. In many species, as for instance, oaks and sweet chestnut, heart-shake is present before the tree has been felled, or sawn; in other cases it is due to felling, or happens after it has taken place, as in Scotch pine, beech, hornbeam, silver-fir and spruce (being commoner with silver-fir than spruce). It is then caused by a shock from another tree, wind, or the action of felling with the saw, for experience has shown that this defect is more frequent with sawn trees than when they are felled with the axe.

The cause of this defect is often shrinkage of the wood, and it is more frequent the thicker the stem and the drier the heart-wood when compared with the sapwood, comparative dryness of the heart of the tree causing radial cracks. Injected round timber, which has been exposed to strong pressure at the transverse section, is also very subject to heart-shake.

The only means of protecting heartshaken wood from splitting further, consist in slowly drying the affected wood; hence trees felled in winter are less subject to this defect than summer-felled wood. Wood intended for water-pipes is protected from heart-shake by boring it out as soon as it has been felled.

Simple heart-shake does not render timber unfit to be sawn into planks and scantling, provided the axis of the tree is fairly straight and the cracked part can be removed by two cuts of the saw; timber with star-shake can scarcely be used in this way, even when only a few large cracks occur.

(b) **Frost-cracks.**—These are long radial clefts in the wood running up the stem, which originate in the bark and penetrate more or less deeply into the sapwood and heartwood; they often split the stem from a good height, down to the roots, or the reverse. They are caused by circumferential shrinkage, generally due to sudden extremes of cold, as explained in detail under Forest Protection.*

The crack closes again, as the temperature rises and becomes occluded by a new growth of wood, especially if it is not deep;

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* *Vide* Manual of Forestry, vol. iv. p. 435.

should a number of annual zones of wood cover it, the value of the timber may be only slightly impaired. This is frequently the case with conifers, where the slight crack which remains in the interior of the stem becomes filled with resin, preventing any decay of the wood.

Very frequently, however, and especially in the case of broad-leaved trees, frost-cracks which are only superficially occluded are opened again and again in the winter, year after year; the occluding wood then gives rise to a prominent ridge, termed a frost-rib (figs. 8 and 9), and the wood then becomes unsuitable as timber. These frost-ribs are developed in a very marked way on the north side of young elms and oaks [but may occur on any side of a tree.—Tr.]

Fig. 8.

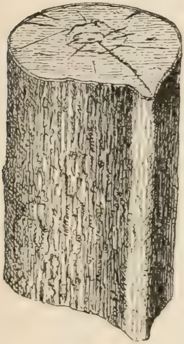
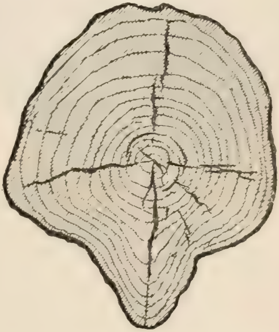


Fig. 9.

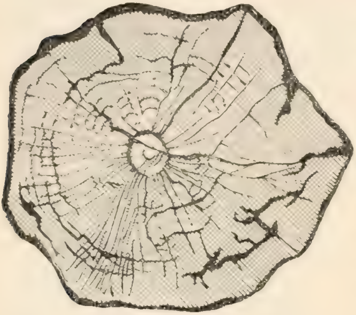


The great damage done by frost-cracks may be readily observed on the transverse section of many old standard trees, as in fig. 10. It is clear that such damage must introduce decay into the wood and render it useless except for fuel.

Frost-cracks are more frequent in the case of large and isolated trees than in crowded woods; they also commonly occur at places in stems where the density of the woody texture varies, as at the base of a tree and the junction of broken or dead branches with the stem. Trees which split easily, and those with large medullary rays, are also very subject to this defect.

Of woody species, oaks, sweet chestnut, limes, horse-chestnut, elms and beech are most subject to frost-crack, but silver-fir, spruce, larch, ash, sycamore, maple and birch do not escape. Whenever a stem has suffered from frost-crack, its utility as timber is very questionable; even when a long crack has been completely occluded, the stem cannot, in the case of oak, be used in the round and rarely for staves. If, however, a frost-rib has formed and decay commenced, only certain parts of it can then be used as timber. In this and many other cases of defect, the extent of the damage done is a matter for appreciation, after the tree has been felled.

Fig. 10.



Frost-crack and cup-shake.

(c) **Cup-shake.**—Cup-shake occurs when some of the annual zones of the timber have separated partly or entirely from one another; sometimes such clefts may meet at their ends, and surround a loose central axis of wood and are termed **ring-shake**, but usually they do not extend so far (fig. 10). They are due to different causes: sometimes to shrinkage of the central part of the tree, probably owing to its drying-up; in many cases to the action of fungi, as Hartig has shown in the case of Scotch pine, spruce, silver-fir and larch, where ring-shake may be due to *Trametes Pini*, and proceeds right up the stem. Ring-shake may be caused after frost when a thaw suddenly sets in and expands the sapwood, separating it from the central woody zones [and also by a forest fire.—Tr.].

Cup-shake frequently occurs at the junction of two woody zones of unequal dimensions, especially in the case of silver-fir and spruce which have grown slowly as underwood for a number of years and have then suddenly been exposed to full light. The action of the wind also causes cracks of all kinds.

Duhamel states that willow-pollards show as many cup-shakes as the number of times they have been pollarded. As a rule cup-shake does not proceed far up the stem and is most frequent in old trees; it frequently extends only for a few feet in height, but may proceed to the top of the stem. The defect is commonest in the case of old silver-fir, larch, oaks, beech and many softwoods, but scarcely any species is exempt from it.

Cup-shaken wood cannot usually be sawn, but may be split into staves. The use that can be made of such wood evidently varies with the extent of the defect in question.

(d) Abnormal Direction of Fibres.

i. *General Account.*

An abnormal direction of the fibres in a stem renders wood unfit for use in construction of buildings, &c., but may give it a certain value for cabinet-making. Under this heading are included, **occlusion of wounds, burrs, wavy wood** (curls), **twisted fibres and knottiness.**

ii. *Occlusion of Wounds.*

The wood covering old wounds caused by loss of bark, or the pruning of large branches, readily detaches itself from the subjacent wood, and is formed of fibres irregular in direction. It cannot therefore generally be utilized except for fuel.

iii. *Burrs.*

Burrs are due to the extensive production of dormant buds, round which the fibres wind abnormally; they are also due to injuries and pruning. Burrs are commonest in poplars, elms, walnut, ash (the finest ash-burrs come from Hungary), alders, birch (birch-burrs are termed Swedish lily-wood in the timber-market), maple (silver-maple or birdseye-maple, fine specimens of which come from America), also in oaks and limes. Burrs are usually found low down on a stem, and are commonest with trees grown in the open, not in closed woods. They are usually sawn into thin veneers and used for the fronts of piano-fortes and other ornamental cabinet-making work. They are produced artificially by lopping ash-trees.

iv. *Curls or Wavy Wood.*

Curls (or wavy wood) are formed when the fibres bend from side to side, but do not cross one another; they occur in beech, ash, alder, oaks and spruce, especially near the roots of the trees, the texture becoming normal higher up the stem. Curls are common in beechwood above the insertion of the branches. Curls are valued by the cabinet-maker, but useless for carpentry.

v. *Twisted Fibre.*

Twisted fibre occurs when the grain of the tree winds spirally round its axis. This may be either from the left to the right hand of an observer stationed in front of the tree, or the reverse. The former direction is opposed to the apparent diurnal motion of the sun, and the latter is with it. As a rule the direction of the twist is constant throughout the tree, but in some trees alternate zones of wood twist in opposite directions.

In the case of the pyramidal or Lombardy poplar, the torsion is always from right to left, and the reverse in the horse-chestnut.

In most European forest trees, the torsion is from right to left, especially in the case of the spruce. Torsion is common in the following species:—Scotch pine, horse-chestnut, oak, sweet chestnut, spruce, elm, beech, white poplar; it is rarer with birch, alder, silver-fir, ash and sycamore. Although torsion is commonest in trees grown in the open, it is nevertheless not infrequent in dense woods, especially with oaks. In the case of Scotch pine the degree of torsion may be so excessive that the direction of the fibres twists completely round the stem within a length of 5 to 7 feet. Fossil conifers have been found with twisted fibre. Torsion of fibres is sometimes so frequent that the trees in whole woods may be so affected. There is a Scotch pine forest near Trier where 84 per cent. of the trees have twisted fibre, and other similar cases occur in the Bavarian Alps, and in Switzerland.

Torsion, according to Alexander Braun, is partly caused by a sloping direction of the cambium-cells and partly by their great length, so that there is no room for them in a vertical direction. In fact it is only a question of degree, for in most trees the fibres will be found to wind spirally round the stem, if their direction is followed far enough.

Wood with twisted fibre is not suitable for planks, which usually warp when sawn from such trees, and does not make good scantling or beams, as their strength is greatly reduced by the saw having cut through the fibres. All sawn wood with twisted fibre must be planed in opposite directions along its opposite faces. Coopers reject such wood for their staves, and probe standing trees to test the straightness of the fibres. It may be used for short split pieces, and also in the round, or as **wany-beams.***

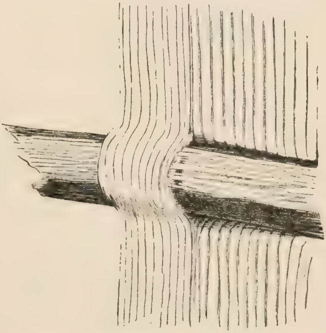
The custom followed in many districts in Germany of preferring wood twisted from right to left to that twisted in the opposite direction appears to be due to prejudice, for in other districts no difference is made in this respect.

[Many woods of hot countries naturally have bent fibres, and that of Guaiacum wood (*Lignum vitæ*), from the West Indies, may be quoted; in this, the grain bends from right to left and back again, and frequently cuts the vertical at an angle of 45°, assuming different directions in successive narrow layers. Such wood cannot be split radially and only with great difficulty tangentially, and is therefore very useful for pulleys, bowls and other purposes where toughness is required and weight is no objection.—Tr.]

vi. *Knottiness.*

All branches which have become enclosed in the wood give rise to knots (fig. 11). Whenever trees, and especially light-demanders, have been grown in dense woods, they free themselves early from their lower branches, and large knots do not occur in their wood. Trees grown in the open, and many shade-bearers, even when grown in dense woods, are not free from knots; though their lower branches may eventually die, and become enclosed in the wood, such knots are always liable to become loose after the stem has been sawn-up, and thus leave holes in the planks, which considerably reduce their value.

Fig. 11.



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* *Wane* is the natural rounded edge of a log.

In conifers, also, such dead knots become saturated with turpentine from the wound which surrounds them; this hardening into rosin causes the horny knots found in larch, pines, and spruce, when grown in the open.

Wherever the lower branches of conifers have been pruned close to the stem, either to improve the timber, or for litter, this being generally done when the trees are about twenty-five years old—the stem appears outwardly to be free from branches, but their remains will be found on a section as shown in fig. 12, and defective planks will result. Hence, to be effective, pruning must be done early in the life of a tree, but the natural pruning of the branches due to crowded growth of the trees from the first gives far better results.

FIG. 12.

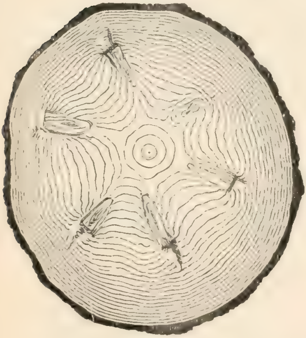
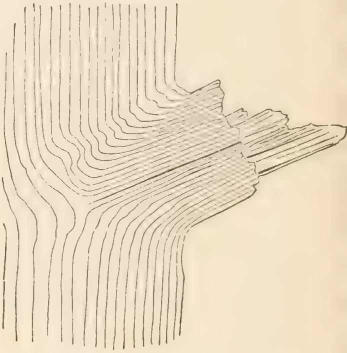


FIG. 13.



Where green branches are allowed to remain on the trees they certainly alter the direction of the fibres and form **snags** (fig. 13), but the resulting knots are firmly connected with the stem-fibres, and do not fall-out, and they prejudice the value of the planks much less than the dead knots already referred to. In fact, spruce, silver-fir, and beech, grown more or less in the open and branched deeply down towards the ground, and especially the Cembran pine, often supply finely marked timber, which is prized by the cabinet-maker.

The worst knots are those running right across the breadth of a plank, which greatly reduce its strength. In the case of larch, knots are frequently as hard as bone, and altogether resist the action of planes and saws. Silver-fir knots are usually very dark-coloured, and thus reduce the value of this timber. The transverse strength of beams is evidently reduced by the presence in them of large knots. In order to avoid knottiness in timber trees must be grown in dense woods, especially when young.

Scandinavian timber containing many knots is often falsified by boring away the surface of the knots on both sides, and filling the place with a mixture of wood-chips and glue.

(e) **Damage by Game and other Injuries.**—Damage done to timber, especially in parks by deer, which peel the bark of trees, or rub their antlers against poles, may frequently be detected deep-down in spruce and other timber, although it has been completely occluded and enclosed within the wood of the stem. In fig. 14, *a*, *a* is the exposed wound, *b*, *b* the occluding wood which eventually produces regularly formed annual zones at *m*. The surface of the wound is always dark brown, and the woody rings above and below the wound are also usually dark coloured. Such stems cannot generally be used, either in the round or as scantling.

Fig. 14.

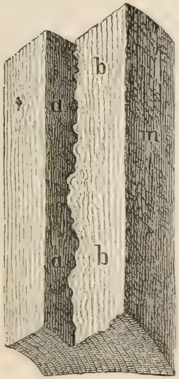
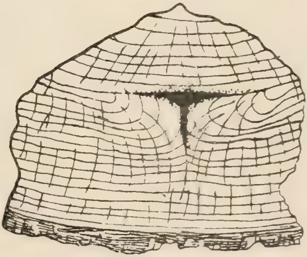


Fig. 15.



Rindgall.

(After Fernandez.)

[Similar damage is done to trees by the abrasion of their bark by cattle, cartwheels or during fellings, when one tree falls against another; these cases are described under Forest Protection. Small defects due to local loss of bark, which have afterwards healed over, are termed **rind-galls** (fig. 15).—Tr.]

(f) **Internal Bark.**—Whenever two or more terminal shoots of a tree have grown close together during its youth and become enclosed in one stem, the timber is useless except for firewood. This defect, as exemplified in fig. 16, occasionally occurs in spruce-trees planted or sown on very rich soil: forking also results from injuries by frost, snow, game, &c.

Fig. 16.

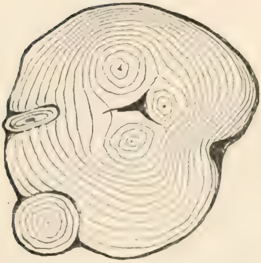
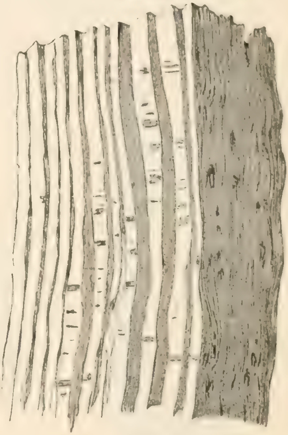


Fig. 17.



[In tropical countries, internal bark is formed naturally in certain trees and climbers, such as *Dalbergia paniculata* and *Bauhinia Vahlii.*—Tr.]

(g) **Damage by Mistletoe.**—Mistletoe often causes the wood of silver-fir and other trees to be riddled with holes (fig. 17). This is chiefly in the upper part of the tree, and thus the length of many otherwise promising logs must be reduced, as this riddled wood can be used only as fuel, and even then is difficult to split. [*Vide* Manual of Forestry, Vol. IV., p. 366.—Tr.]

(h) **Damage by Resin-tapping.**—Resin-tapping may also cause stems to assume a curious fluted shape. When spruce and black pine are repeatedly tapped for resin from an early period in their lives the lower part of their stems may become quite unfit for timber, especially if decay ensues, as is usually the case.

[The only European tree which can be economically tapped for resin is the Cluster pine, provided the trees are not tapped till sufficiently large to be used for railway-sleepers, small beams or pit-timber; the wood then becomes very hard and heavy from the accumulation in it of resin, and if all the part which has been tapped is removed after the tree is felled, being fit only for firewood, the inner untapped portion of the wood may be utilized, as above.—Tr.]

(i) **Resin-galls.**—The so-called resin-galls in the interior of stems of old spruce and other conifers are also prejudicial to the use of these stems as timber. H. Mayer states that these galls are due to the fact that during the active life of the cambium, resin is pressed into the cambium-zone from the horizontal resin-ducts, these deposits of resin being afterwards occluded, as in the case of wounds. Isolated trees are more subject to resin-galls than those grown in a dense wood.

2. *Defects in Timber owing to Disease in the Woody Fibres.*

(a) General Account.

The resistance which wood offers to decay will be described in the section on the durability of timber. At present, the only question is as to the extent to which standing trees which have become decayed may be utilized.

The ultimate materials into which decomposed wood is reduced are carbon dioxide, ash, water and the intermediate products termed humus. Decay in living trees may be distinguished by the colour, as wood suffering from **red-rot** or **white-rot**; the **greenish colour** of some rotten wood, chiefly beech and oak-wood and due to a fungus (*Peziza æruginosa*), being of rarer occurrence. Decaying felled wood suffers from **dry-rot.** As already stated under Forest Protection, the mycelia of fungi contain ferments, which act on the cell-walls; some of these ferments decompose the lignin only, leaving whitish cellulose, and others the cellulose, leaving dark ligneous substances.

Decay in standing trees may be effected either by means of parasitic fungi, which obtain entrance into the wood through the roots, or through wounds in branches, &c.; or may be owing to want of oxygen in the soil, or to moisture and air from the atmosphere penetrating through external wounds, in which fungi eventually grow. Whenever wood is attacked by parasitic fungi the evil spreads rapidly, the wood losing its coherence owing to the growth of the mycelia and the decomposition of the cell-walls, and assuming various colours* and appearances, according to the kind of fungus which attacks it.

Red-rot is caused in the spruce and silver-fir by *Trametes radiciperda*, *Polyporus vaporarius* and *P. mollis*; in the larch, oak, poplars and willows, by *P. sulphureus*, and in the oak also by *Thelephora perdix*.

White-rot is caused in the silver-fir by *Polyporus fulvus* and *Agaricus melleus*; in the spruce by *P. borealis* and *A. melleus*: in the Scotch pine, Weymouth-pine, and larch, by *A. melleus*; in the oak by *P. igniarius*, *P. dryadeus*, *Hydnum diversidens*, and *Stereum hirsutum*; in the beech by *Hydnum diversidens*.

Root-rot is commonest with the Scotch pine, and rarer in the case of the spruce and other species, and causes a kind of white-rot.

All decay due to wounds first causes a dark brown discoloration of the wood (red-rot), which may eventually turn into white-rot; the products of the decomposition are often carried far, both upwards and downwards, into the stem by the sap. Such decaying wounds continue to increase only as long as the wound is open and rain-water gains admission into the tree. The part of the tree infected, the amount of infection, and its influence on the future utility of the wood, are naturally very variable.

(b) Decay of the Separate Parts of a Tree.

A distinction can be made between decay within the tree itself and external decay.

i. *Internal Decay.*

The interior of a tree may be decayed without there being any easily apparent external signs of the damage. Such decay commences either at the roots or through the branches or wounds in the bark, and penetrates to the interior of the tree. It may be either red or white-rot, and may extend only to the **roots, stem or branches.**

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* [These are very clearly shown in coloured plates given by Hartig in his *Baumkrankheiten*, which are not, however, reproduced in the English translation of that work.—Tr.]

Root-rot may occur in all species of trees. Old trees have usually some of their roots rotten, especially the tap-root and other central roots; their large spreading side-roots then nourish the tree, in which frequently rot of the central heartwood has commenced. The appearance of side-roots above the surface of the ground is often a symptom of root-rot. Isolated aspen, birch and sallows found in beechwoods often suffer from root-rot, and especially the first when it springs from suckers.

Scotch pine, spruce and other conifers frequently suffer from root-rot, when the soil in which they are growing is not sufficiently supplied with oxygen, and is cold, wet, or too compact.

In many cases unsuitable soils cause root-rot, but fungi do so as well, as *Agaricus melleus* and *Trametes radiciperda*. As long as root-rot does not proceed up the stem, it is not technically of much importance.

Branch-rot is caused by the death of large branches, windbreak and lopping of trees. It usually spreads very slowly down into the stem; when, however, spores of parasitic fungi germinate in the wounds, decay may spread rapidly throughout the whole tree.

Stem-rot, usually of the heart of the tree, is the worst form of rottenness, and arises from root-rot or branch-rot, and may sometimes affect the sapwood as well as the heartwood. In certain cases the whole central part of the stem may have become decayed, from the roots upwards. As a rule, however, only the lower part of the stem suffers, and in some cases decay may be localized to certain parts of the stem. When a tree has been felled during the growing season the sapwood often becomes decayed to a depth of 2—4 inches. In all these cases either red or white-rot may be present.

Red-rot is very common in the case of old spruce, silver-fir, oak, sweet chestnut, elms, aspen, pollard and maiden willows, the beech, hornbeam, sycamore and maples being more subject to white-rot. On the whole, although all species of trees may suffer from either red or white-rot, the latter is rarer, but may follow red-rot in the same tree.

Decay spreads most easily along the grain of the wood, and also centrifugally, but is often localized in a certain part of a tree. According to the direction of the section made in the wood during conversion, the decayed places will assume different forms. Thus a transverse section may show spots, or zones of decay, termed *Mondring* in German, or *lunure* in French. Spruce and silver-fir left unbarked show bluish or black sapwood. When the stem is sawn into planks, the decaying parts show like red, or white, lines and stripes. The wood may often be penetrated by repeated decaying stripes, as in old oaks attacked by *Stereum hirsutum*. [Said to be white-piped.—Tr.]

ii. *External Decay.*

Whilst decay in the interior of the stem may often be completely concealed under an apparently healthy exterior, there are other forms of decay which affect the bark, and can therefore be readily recognized. Such decay is due to fungi of different sorts, chiefly those which cause canker. Frost-cracks, or injuries of all kinds, and insects, facilitate the admission of the spores of fungi. Thus silver-fir canker is caused by *Æcidium elatinum*, larch-canker by *Peziza Willkommii*, and species of *Nectria* cause cankers in beech, ash, sycamore, and other broad-leaved trees.

Frost-cracks which remain open for some time are the commonest causes of decay in trees. The fungi then penetrate down into the heartwood, and cause the rotten radial cracks which so often accompany frost-crack, and if the cracks should close and no further progress of decay in the stem take place, yet even then it will only be fit for fuel.

All injuries done to the bark of trees which extend as far as the sapwood may admit spores of fungi and cause decay. If the injury is merely in the bark, corky tissues are formed which protect the wood below from injury; but once the cambium is laid bare, the wound can be closed again only by the spread of a callus from its sides, and, as long as occlusion* has not taken place, there is always danger from the spores of fungi.

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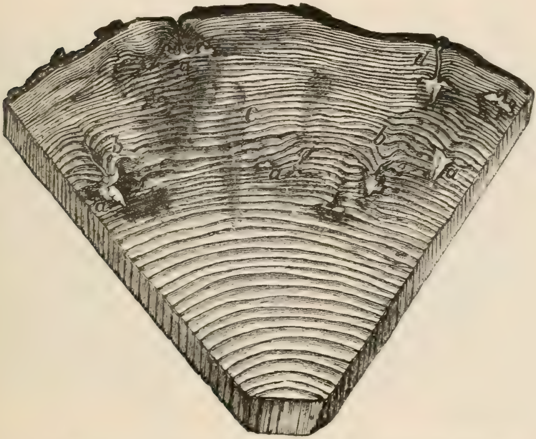
* For a full account of the process of occlusion of wounds, *vide* Hartig's *Baumkrankheiten*. (Translation by Somerville, edited by Marshall-Ward.)

[In hot, moist regions, as in India, the power of occlusion is much more rapid than in Europe, and the translator has seen large clean wounds in mango trees become completely occluded within a few years.—TR.]

Wounds arise from blazing, cutting letters, peeling by game, abrasures of bark by a falling tree, lightning, hail, the use of climbing-irons, &c.

Hess has repeatedly drawn attention to the serious damage done to trees by the use of climbing-irons, which may render their future use as timber impossible.

FIG. 18.



a. Wounds by climbing-irons. *b.* Wavy wood occluding the wounds. *c.* Dark patches of incipient decay. *d.* Unoccluded wound.

Pruning living branches may be added to the above forms of injuries, unless certain precautions are taken. Whenever a stump of a branch is left without a small sap-lifting branch to assist its occlusion, this stump gradually decays and communicates decay to the trunk of the tree. If a blunt stump pointing upwards be left, it may eventually become occluded, but a knob is formed which usually covers decay. Such unsound knobs are common in broad-leaved trees, and are frequently due to the breakage of a branch.

If, on the contrary, the cut of the pruning be close along the stem, and thus lying in the direct course of the sap, the process of occlusion is greatly facilitated; once a cushion of callus (fig. 19) is formed, it closes-in each year on the wound, and covers it over more or less rapidly, according to the rate of growth of the tree and the size of the wound (fig. 20). It is certain, however, that wood so exposed for several years must dry

FIG. 19

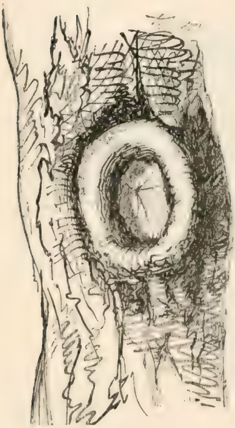
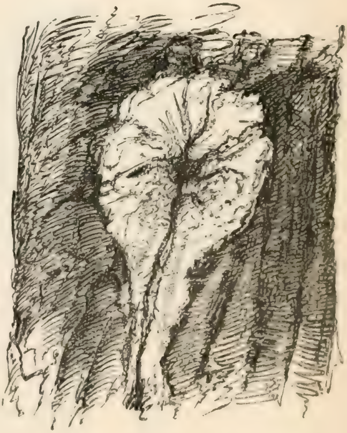


FIG. 20.



and shrink, and become at least slightly decomposed, whilst all this time it is exposed to the entrance of spores of fungi, which may cause rapid decay, extending to the heartwood of the tree. [Broillard recommends that in the case of oak, no pruning should be done after any heartwood has formed in a branch.—TR.] The turpentine which flows from such wounds in conifers, and hardens into resin on their surface, protects them to a certain extent from fungi; in the case of broad-leaved trees such protection should be afforded by smearing the wound with coal-tar. All closed wounds exceeding two inches in diameter should be looked on with suspicion.

iii. *Amount of Damage done to Timber by Decay.*

It is hardly possible to state which species of trees are more liable to decay than others. In certain cases the question arises as to the extent and stage of the decay, before the disposal of the wood can be decided.

Locality has far more influence than species on decay. There are certain woods in which most of the spruce are suffering from red-rot, and others where it is rare. Similar results occur in the case of Scotch pine, for while in North Germany, fungus-attacks on trees are common, they are scarcely known in the greater part of South Germany.

The **Age** of the woods is another cause of decay, and superannuated woods always contain more diseased trees than younger woods. The **mode of treatment** which has been adopted, and whether lopping, pruning or pollarding is allowed, is also of considerable influence on the soundness of the wood.

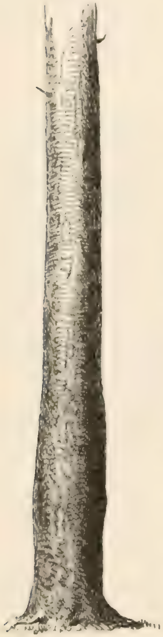
The difference in this respect between coppice and seedling-plants is important; aspen and alder coppice-shoots are frequently decayed, whilst trees of these species sprung from seed remain sound.

Trees may be in very different stages of decay, from its first appearance to utter disintegration of the tissues, and their relative value under these different conditions will vary considerably. Thus silver-fir and spruce logs left lying through the winter get blue sapwood due to a fungus (*Ceratostoma piliferum*), and red stripes may appear on the surface of the logs. In such cases it is important to decide whether by proper treatment the wood may not still be fit for use as timber. Practical tests for this are found in examination of the ends of the log, of its degree of hardness, dampness, odour, colour and sound given out when struck with the butt-end of an axe. In the case of standing trees, the appearance of the crown, branches and stem may be used to determine their condition.

The sections at the two ends of a log are often indices of the state of soundness in the case of species subject to decay along the stem.

In many cases, the scent of the sawdust is an excellent guide to the soundness of the wood; thus sound oakwood possesses the well-known scent of tannic acid, whilst in the case of many diseases of coniferous wood, a strong scent of turpentine is observed. Several other species have scents peculiar to themselves, but which cannot be described. Whenever the scent is unpleasant and mouldy, it is a proof of more or less advanced decay.

FIG. 21.



The colour of fresh sections of wood offers an excellent test of its soundness. Uniformity of colour, and for most species the lighter tints, are usually signs of soundness. Patches or stripes of darker colour in a wood prove the opposite. In the case of spruce and silver-fir even a very slight brownness of the wood is a bad sign, and such wood should be unquestionably rejected for use as timber. In the case of oak-wood, bright or brownish yellow colour is a healthy sign, and even a rosy colour would not prevent its use as timber, but brownish or cinnamon-red and dark brown colouration are highly suspicious. Green colour is a sign of complete decay. Dark blue colour of coniferous wood felled during the growing season and not barked, points to a commencement of decay in the cambium and sapwood.

Striking the reverse of an axe against a stem at different places, from the clear or dull sound given out, leads to conclusions as to the soundness of the tree. At the same time the practice of one man striking at one end of a log and another placing his ear at the other end affords no certain test of soundness. The best way to test an occluded knot in a tree is to remove the new wood over the wound, and probe the latter with a knife or other tool.

In the case of standing trees, the detection of unsoundness is naturally more difficult than for logs, but the condition of the crown and branches may give useful indications in this respect:—whether for instance the tree is stag-headed, or has any large dead boughs or snags, whether during the growing season the foliage is complete, or partly dead.

A uniform appearance of the stem, in its shape and bark, is a good sign; abrupt swellings in the lower part of the stem are bad signs (fig. 21), and usually indicate root-rot in the case of spruce. Local differences in the texture of the bark, extensive splitting, blistering, or conspicuous smoothness of bark, are bad signs. The presence of knots, fungi, frost-cracks and cankers, the exudation of rotten sap from wounds, entrance of ants, beetles, mice or weasels into holes among the roots, the tapping of wood-peckers or of nut-hatches—all these are signs of decay in a tree.

iv. *Market Value of Unsound Wood.*

Our object must be to use only sound wood as timber, but pieces which are only slightly affected by disease may still be used for certain purposes. The oak and some other species are seldom entirely free from some defect or other, and these may be insufficient to prevent its use, but in all such cases the wood must be at once throughly dried, and only used in dry places under cover. If then the fungi which are causing the decay should be killed by drying, and the wood has not become too weak for the purpose in view, there need be no fear of any increase in the decay, and the wood may still be serviceable.

It is clear that whenever the timber-market is well supplied, there will be a much greater difficulty in disposing of doubtful material than when the supply is small, and the demand great.

SECTION XII.—DURABILITY.

1. *General Account.*

Durability is a measure of the duration of time during which wood utilized in a certain way will last in a sound and useful condition. This is the most important quality for timber, the first question to be asked as regards any wood being whether, or not, it is durable.

When a wood no longer forms part of a living tree, like all organic bodies after a longer or shorter interval of time, it becomes subject to gradual decomposition, as the substances of which it is formed tend to revert directly, or indirectly, to the air and soil from which they were originally taken.

The causes of this decomposition are fungi and animals (chiefly insects). There can be no doubt that fungi are the chief causes of the decomposition of all organic substances, and this Hartig has shown in the clearest and most convincing manner as regards wood. Fungi gain access into wood by infection, partly by mycelia, but chiefly by spores; if circumstances favour the spread of the latter, the mycelia of the fungi grow in and among the wood-cells and fibres and by nourishing themselves on their walls and contents break-up and destroy the woody tissues. The destructive powers of insects will be dealt with presently.

Wood is most subject to decay when it still contains sap. Woody fibre, freed from sap and from the reserve nutritive material which plants store in their woody tissues, is almost imperishable, dampness being absolutely necessary for the growth of fungi. Sappiness of wood is also a great furtherance of the attacks of insects, for they prefer reserve-materials to pure woody fibre. Wood-sap consists of water in which various substances such as starch, dextrin, sugar, colouring matters, etherial oils, tannins, albuminous substances, &c., are dissolved, or suspended in grains or crystals.

It is well known that different woods are in different degrees subject to decay, and that many woods, and the same wood under different circumstances, possess different degrees of durability. The chief factors determining the durability of a wood are its nature, its treatment since it was felled and until it is utilized, and the external influences and media to which it has been exposed after utilization.

2. *Nature of the Wood.*

From what has gone before, it may be easily imagined that the specific gravity of a wood is a powerful factor in determining its durability, and after this comes the question of its sappiness and its degree of soundness.

(a) The specific gravity of a wood taken alone, affords no conclusive argument as to its durability. Several light woods, as for instance conifers, may be more durable than heavier woods like beech, birch and maples, but in the case of the same species, the heavier wood is always the more durable. The amount of woody substance a wood contains is also important, so that dark summer-wood is more durable than light spring-wood. As regards ring-pored woods, such as oak, ash and elm, broad-zoned wood with comparatively narrow porous zones and with small pores is more durable than narrow-zoned wood. Thus, for instance, a cask made of narrow-zoned porous Spessart oak seldom lasts without repairs more than 10–15 years, whilst a broad-zoned oaken cask, the wood of which was grown near the Rhine or Moselle, or in France or Hungary, may last for 30–40 years and more. In the case of conifers, on the contrary, as a rule, narrow-zoned wood is more durable than broad-zoned wood.

A. Mayr states that intense coloration of heartwood is also a measure of the durability of timber. Faintly coloured heartwood resembles sapwood in its properties, surpassing it only owing to its superior dryness. The colouring matter of heartwood is antiseptic, but intense heat and light are required to produce tannin, so that woods from the south are most durable.

Whatever local circumstances may increase the specific gravity of wood of a certain species, will also increase its durability. Thus, heavy coniferous wood of the lower and middle Alpine zones is more durable than light coniferous wood grown in warm lowlands; on the other hand, heavy oakwood from the vine-region of Europe has been proved by experience to be more durable than oakwood from colder localities and poor soils. As regards most broad-leaved trees, more durable wood is produced in the open than in dense woods. This is directly the result of the increased effects of light on the density of wood, and its truth has long been proved by experience. (*Vide* Plates I. and II.)

(b) **Wood-sap** is, as has been already stated, the most frequent cause of the entrance of wood-destroying fungi. The possibility of the greatest durability of which any wood is susceptible therefore depends on the tree being felled when it contains least sap. It is well known that the amount of sap in a tree varies with the species, and that as a rule, broad-leaved trees contain more sap than conifers, and as regards parts of trees, that the sapwood usually contains far more sap than the heartwood. The amount of sap also depends on the extent of the root-system, and to a great extent on the season; in general, spring and summer are the seasons of greatest sap, and autumn and late winter the seasons of least sap in trees. The latter point is the most important of all as regards utilization, and leads us to the question, **when should trees be felled**?

It is still a much disputed question whether winter- or summer-felling is to be preferred to ensure the greater durability of timber, and this cannot be satisfactorily answered without considering the future destination of the timber after it has been felled. In case the wood is to be thoroughly dried immediately after the felling, and then converted and utilized, it is a matter of indifference whether it is felled during the winter or summer, for the destructive agency of fungi is excluded, as long as the timber is dry. As a matter of fact, however, such an immediate drying of the felled timber is rarely, if ever, thoroughly carried out. On this account, and since the danger from infection by fungi is greater when the timber is felled during summer than when it is felled during winter, in most cases **winter-felling is certainly to be preferred to summer-felling.** If, however, winter-felling is impossible, trees should as a rule be felled as late as possible in autumn.

When trees are felled during winter they generally contain less sap than in summer, the activity of wood-destroying fungi is either very slight or altogether nil, and the new wood is fully lignified. In winter, however, it is more difficult to bark logs completely, or in many cases to bark them at all, so that winter-felled trees lying in the forest dry very slowly, though they are at any rate protected from cracks and splits.

Wood felled during summer is usually completely barked, in order to facilitate transport and to protect it from insects ; in this condition, the wood, owing to the comparatively dry summer air, dries rapidly in the forest ; it is thus liable to split and crack, often in a serious manner, and during rainy weather is thus exposed to the admission of the spores of fungi. The latter might not cause any injury, if the wood were to become dry to its centre ; but if, as is usually the case, this is not secured, and the wood remains more or less damp for some time, the spores of the fungi will develop into mycelia, and dry-rot ensues.

In localities high up in the mountains, summer-felling is frequently a necessity, on account of the depth of the snow till

May [though if felling, as in the Himalayas, can be effected in spite of the snow, the latter will prevent breakage of the falling trees and the crushing of valuable underwood.—Tr.] It may not be possible to fell during winter, and woodcutters frequently prefer to fell large timber in the height of summer, as the stems can then be readily barked and prepared for winter-transport. July and August are, however, the very months when the danger of infection by fungi is most formidable. Whenever, therefore, in such places there is reason to fear that felled timber cannot be dried readily, it is advisable to defer the commencement of the fellings till September, and continue the operations till winter commences. Even if the logs can be only roughly barked, and the bast left on them, they will be the better preserved. Whenever there is no strong objection to winter-felling, it should certainly be adopted.

Since the reserve-material contained in woody tissues is the chief medium of decay in wood, it is evident that timber felled immediately after a good seed-year will be more durable than when it is felled before such an event, for the production of seed employs very much reserve-material.

Besides wood-sap and the substances it contains, conifers also contain turpentine and resin in a more or less fluid state. Foresters are often disposed to ascribe an antiseptic property to resin, as it excludes water from wood, and the frequently great durability of highly resinous wood confirms this opinion. The importance of resin, in this respect, must, however, be taken into consideration along with the various wood-destroying agencies, and especially that of fungi. Whilst even moderately resinous Scotch pinewood is as a rule more durable than spruce-wood, the latter, even when highly resinous, may, under certain circumstances, decay as rapidly as silver-fir wood, which is scarcely resinous at all. The high durability of Scotch pinewood is due to its distinct heartwood, and to the fact that this heartwood has become impregnated with resin, which, as the timber dies, replaces water in the walls of the fibres.

(c) That thorough soundness of the wood is needful for durability is evident from the nature of the case. The only question here is, how to decide as to the soundness of a piece of timber. Even experienced timber-merchants may find it difficult to decide in certain cases whether a piece of timber is sound or not, but there are certain marks of sound timber which have been already referred to (p. 77).

There is always a danger when a tree is very old that the resulting timber will not prove sound, and experience shows that middle-aged timber gives better results than very old material. Evidently the danger from fungi, or from rot arising from broken branches, continually increases with the increasing age of a tree. Exceptions may be made here as regards Scotch pine and larch, on account of the increasing proportion of heart-wood and accumulation of resin with increasing age, but this is under the proviso that the tree is still young enough to continue increasing in girth.

3. *Treatment of the Wood after Felling.*

The treatment of the wood after felling is of greater importance for its durability than the season of felling. The nature of the exposure of the wood during its shorter or longer stay in the forest, the methods of transport, and the subsequent mode of storing it until it is converted and utilized, are the chief factors which determine its durability.

In every case, the greatest efforts should be made to avoid everything which might favour infection by fungi and their consequent development; this can be attained only by measures securing a steady drying process from the moment the wood has been felled until it is utilized. If the wood has become infected by fungoidal spores whilst still in the forest, as in the case of summer-felled wood, and it is prevented from drying sufficiently, whilst lying in the forest, during transport and especially when in depot, dry-rot must ensue to a greater or less degree, the extent depending on the interval between the felling and the utilization of the wood.

The powers of resistance of different species against this threatened danger vary considerably; soft broad-leaved species are most exposed to it, then beech, spruce and silver-fir.

Since spruce and silver-fir woods of the higher mountain regions are usually felled during summer, and the logs completely barked, the wood usually cracks and is thus exposed to infection. The wood, raised above the ground on logs, remains in the forest until heavy snow falls, it is then dragged to the waterside for floating, only reaching the sawmills after being many weeks in the water. The firewood, still wet, is often stacked in sheltered places not exposed to free currents of air. The logs are rolled into great heaps in the yards of the sawmills without any cover; balks are also left lying on the bare ground. Whatever wood is at once converted at the sawmill and properly dried, remains free from decay, but logs lying on the ground all through the summer without proper arrangement and only sawn during autumn or winter, or even in the following spring, and half-dry balks worked into new buildings, necessarily become intersected with red and black stripes, spotted and decayed.

Broad-leaved or coniferous wood felled in winter, and partially barked, is not exposed to infection while lying in the forest. If, moreover, all logs are slightly raised above the ground on poles, and carted to the depot, there at once converted and the pieces gradually dried under shelter, and timber only used for building after two to three years' exposure in airy places, then all reasonable precautions have been taken to ensure durability.

If at the present time, more complaints are made than was formerly the case of the rapid decay of building and other timber, especially in districts where spruce is used, the reason for this is to be found in the treatment the wood meets with in large depots, rather than in the forest and during transport where suitable precautions are taken to preserve it, the reverse being the case in large timber-depots. Enormous quantities of logs are collected at the large sawmills in order that work may go on continuously from one felling-season to the next, and just as populous cities spread disease amongst human beings, so do these large timber-depots spread spores of fungi in timber. Formerly the logs were distributed amongst a great number of small sawmills, and the wood was converted and dried rapidly.

It is also evident that the half-dried wood used in buildings, when houses are cheaply constructed, cannot be durable.

It is for engineers to insist on being supplied with thoroughly seasoned timber, and wood-merchants will then take the necessary trouble to provide it.

4. *Utilization of the Wood.*

The external influences, or environment in which wood is placed, must have very great effect on its durability. Thus, there is a great difference when wood is used in wet or dry places, and whether it is more or less subject to free air-currents and heat, or more or less in contact with the ground.

(a) **Wood used in Dry Places.**—Wood used in places which are nearly or completely dry is very durable, for moisture is necessary for the development of decay. This is clearly seen from the condition of wood in the interior of buildings, where furniture, carvings, mummy-cases and other wooden effects of the most various kinds remain unimpaired for centuries, and even thousands of years, without showing the least decay of their woody fibres. If we exclude the danger of attacks by insects, and only consider that by fungi, wood of all species is extremely durable when kept in dry places, even that of beech and birch, which are not otherwise considered durable woods.

When, on the contrary, utilization in dry places means that instead of being kept in rooms artificially heated during winter, wood is used in places which directly communicate with the external air and its varying humidity, such as sheds, or open garrets, it is evident that wood-destroying organisms may develop, and the conditions of durability are very different from those in the former case.

It is matter of everyday occurrence that wood merely sheltered from above may become rotten, and that in such cases firewood may lose a part of its heating-power, and timber its strength and elasticity.

Grubs and imagos of different insects also destroy wood, and wood in the dry state is most subject to this form of destruction. Without including grubs which destroy the cambium between the wood and bark, and which may be brought from the forest with the wood into the timber-yard, and sapwood beetles, it is chiefly the death-watch beetle (*Anobium** *striatum*, A.), and *A. pertinax*, L., which are most destructive to old dry wood, and reduce furniture and other wooden articles to powder. Several species of *Ptilinus* in broad-leaved wood, and *Anobium molle* in coniferous sapwood, are also commonly found in dry wood under cover.

Broad-leaved trees, especially when felled in summer, are more susceptible to attacks of insects than conifers, and the woods of beech, alder and lime suffer most from insects.

In large timber-yards oakwood is chiefly exposed to destruction by *Lymexylon navale.*†

Among conifers those richest in resin, and then juniper and the Cembran pine, are least exposed to be worm-eaten.

[Bamboos are extremely subject to be worm-eaten, especially the yearling culms, which are very soft and sappy. Only 3 to 5-year-old culms which are thoroughly lignified should be used as rafters, and these only after several months' soaking in a tank, or after being floated long distances in rafts on a river. The natives of India believe that bamboos felled during bright moonlight nights become worm-eaten much more readily than those felled during the dark half of the month when the moon does not shine at night. An experiment was made by the translator at Dehra Dun to determine this, and 100 bamboos were cut during the bright moonlight and 100 cut during the dark part of the month, and the former were much more worm-eaten than the latter. It is probable that certain insects, the larvae of which attack bamboos, fly only during the bright moonlight nights, when they lay eggs in the bamboos.

Whenever poles containing only sapwood, or bamboos, are used for rafters, they should evidently be thoroughly dried ; when exposed to smoke, as they are in the roofs of native huts, the smoke prevents further danger from insects.

The wholesale destruction of most woods in hot countries by termites, or white ants, is well known, and the number of woody species in India which resist their attacks is very limited. Even deodar wood, in spite of the oil with which it is saturated, is sometimes attacked by them, and the sapwood of every wood is eaten away very rapidly. Sal, teak, toon, ebony, sissu and some other hard woods resist their attacks, but in the case of building-timber it is always best to saturate it with *gurjun-* or wood-oil, extracted from species of *Dipterocarpus.* Engineers in India should be careful only to erect solid masonry-walls, and not leave crevices in them up which the white ants may ascend to the roof of a building; they may also mix arsenic with their mortar with advantage.

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* Manual of Forestry, vol. iv. p. 191.

† *Id.*, p. 190.

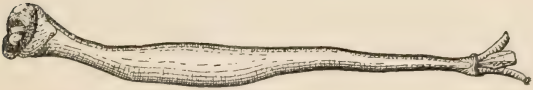
It has often been suggested that softer woods if injected with sulphate of iron or zinc, or corrosive sublimate, would be found to resist the attacks of white ants, but no serious attempts have as yet been made in India to utilize injected wood. This subject will be referred to again in Part III.—Tr.]

(b) **Wood used under Water.**—Wood used under water is very durable, the action of the air which is indispensable for all decay being thus prevented. An essential condition for the durability of wood under water is that the water should be fairly pure, and not moving too rapidly, for rushing water wears wood away. Oakwood, wood of resinous narrow-zoned larch and Scotch pine, and alder-wood, are most durable under water. These are the best woods for use in mill-dams and other immersed works. Silver-fir lasts better than spruce for such purposes.

Even beechwood, otherwise so deficient in durability, may last for centuries under water and has been used for the keels of ships, and spruce and silver-fir last much longer under water than when exposed to the air. In shipbuilding yards the best pieces of timber are kept barked, or unbarked, for four to five years under water, until they are required. Even logs intended for sawmills may be best preserved in this way, and this soaking does not prejudice the future durability of the timber. In the year 1858, the water in the Rhine became exceptionally low, and twelve oak piles of the Roman bridge near Aargau came to the surface, and the wood was found to have become so hard that there was considerable difficulty in turning various toys, &c., which were made from it. Similar durability is shown by oaken piles from the bridge built by the Romans across the Danube, at the Iron Gates, in the time of Trajan, and by oakwood dug from bogs in Ireland and elsewhere.

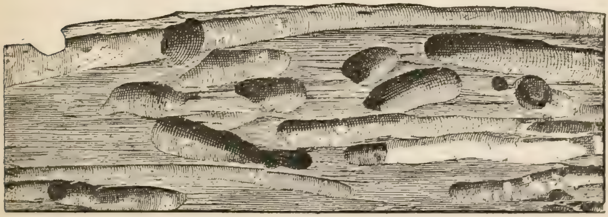
Wood used under water at shipping ports and stores of wood kept under water at these places, are subject to the attacks of certain animals. Some small crustaceans, *Limnoria terebrans*,* Leach, and *Chelura terebrans*,* Philippi, bore into and gnaw the surface of all woods in sea-water. *Teredo navalis*,† L. (figs. 22, 23), and other species of *Teredo*, are however the most destructive pests of south European seaports.

FIG. 22.



The teredo. (After Boppe.)

FIG. 23.



Borings of the teredo. (After Boppe.)

[These mollusks live only in sea-water and bore not only the sapwood, but also the heartwood of **all kinds of timber**, except the jarrah ‡ (*Eucalyptus marginata*). Ships, the bottoms of which are not covered with copper, suffer greatly from their damages.

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* *Vide* Ratzeburg's *Forstinsectenkunde*, by Judeich and Nitsche, 1889, p. 337 *ff.*

† *Vide* Encyclopædia Brit. 1888, vol. xxiii. p. 184.

‡ Laslett, *op. cit.* p. 5.

Wooden piles used in harbours, &c., may be protected by being creosoted, but this is serviceable only when the wood is thoroughly saturated with creosote; as coniferous wood imbibes creosote better than oakwood, it is better when creosoted than oakwood for use in dams and other harbour-works. Attempts have been made to protect piles in sea-water by studding them with broad-headed nails, but the little teredos force their way into the wood between the heads of the nails. In the years 1827 and 1859, when the rainfall was very slight and the Dutch canals near the sea coast became very salt, it was found that all the piles supporting the dams along the Dutch coast were bored by teredos. A Commission was appointed in Holland, in 1859, to enquire into the causes and possible remedies of this damage, and from its report, written by V. Baumhauer and quoted in Ratzeburg's *Forstinsectenkunde* (by Judeich and Nitsche, 1889), the above remarks have been taken. It is also stated by Nanquette,* that when timber is stored in sea-ports for ship-building and harbour-works, it should either be kept in banks of mud, or in tanks in which sufficient fresh-water is mixed with sea-water, so as to render it less saline than is necessary for the life of the teredos.—Tr.]

(c) **Long-continued Exposure to Alternations of Damp and Dryness.**—The durability of woods is greatly reduced when it is exposed to alternations of damp and dryness for any prolonged period, for it is then uninterruptedly in contact with air and moisture, which greatly favours decay. All timber used in water-works and canals—such as piles for bridges; wood-work in canal-locks, and for maintaining the banks of a stream; wooden weirs; the staves of casks; ships, boats and many other constructions and implements—is specially liable to decay. In all these cases experience shows that the wood decays all the more rapidly, the warmer the air-temperature of the locality. Thus, on northern aspects, in cold valleys, in high altitudes and latitudes, the durability of timber is much greater than on southern aspects and in warmer localities. In such unfavourable localities, timber exposed to rapid alternations of moisture and dryness may last for only a few decades, or even a few years, according to the species used. Such an employment of wood is the best test which can be found of its durability for any purpose whatever.

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* *Exploitation des Bois*, 1868.

[It may be noted here as a general rule that the more durable the heartwood of any tree, the richer in reserve-material and consequently the more perishable is its sapwood.—Tr.]

Oakwood, highly resinous wood of larch and Scotch pine, and especially the wood of the different varieties of *Pinus Laricio*, are the most durable European kinds, provided all sapwood has been removed. In the absence of the above-mentioned timbers, and in urgent cases when the supply of building-timber is restricted—circumstances which frequently occur in the construction of works for timber-transport—spruce and silver-fir wood may be used, but always at the cost of durability; these woods are only half as durable as that of larch, which is undoubtedly second only to expensive oak-timber for such purposes.

The decay to which wood, subjected only to wind and weather, is exposed, is, as a rule, much slower than when it is continually kept wet. A number of timbers may be used where exposure to atmospheric precipitations, sunshine and wind only is involved. After oakwood, coniferous wood may be used for the framework of buildings, for fences, gates, roof- and wall-shingles, agricultural implements and other purposes.

(d) **Timber used in the Ground.**—When used in the ground, wood decays rapidly, and so much the faster, the looser, damper, and warmer the soil, and especially the greater the range of dampness and dryness to which it is subject: thus, wood lasts much longer in a compact, damp clay soil, which excludes the air, than in loose, coarse sand or gravel, which is alternately wet or dry. Timber rots more quickly in warm and only moderately damp calcareous soil than in compact loam; and most quickly of all in soil rich in humus, or well manured. Wood is used in the soil for railway-sleepers, house-, gate- or telegraph-posts, and for various agricultural purposes, such as fences, hop-poles, vine-props, bean-sticks, fruit-tree supports, &c. Water-conduits also lie on the ground, but as they are frequently completely buried, and usually contain running water, they are not so subject to decay as wood used for the above purposes. Wood lying on the ground may be even less durable than when in the ground, for the alternatives of moisture and dryness to which it is then exposed are greater than when it is partially buried. The same woods already considered as the most durable when exposed to alternations of moisture and dryness are also the most durable when partially in the ground, and to them the wood of the alder, robinia and sweet chestnut may be added. Split chestnut-coppice wood, according to Forstmeister Kaysing, lasts fifteen years in Alsace as vine-props, whilst barked oak-coppice vine-props scarcely last two years.

[It must however be remembered that peeled oak coppice-wood is entirely sapwood, while sweet chestnut has only 2–4 annual zones of sapwood.

Posts which are placed in the ground usually decay most rapidly near the surface of the soil. To protect them, their butt-ends should be charred or tarred, or better still may rest on masonry-supports and not reach the ground at all. White ants in India live close to the surface of the soil, and bacteria which assist in the decomposition of wood are also more numerous there than lower down, whilst the air which is necessary for their growth and that of fungi is the more excluded, the lower the depth at which any part of the post may be.

At a certain height above the ground the action of the sun and air in drying wood is also more effective, and consequently wood-destroying fungi do not thrive so well as between certain distances above and below the surface of the ground.—Tr.]

Railway-sleepers which are half in and half out of the soil, are very badly situated for durability, as they are exposed not only to continual alternations of damp and dryness according to the state of the weather, but owing to the damp soil below them and insolation of their upper surface, they crack and warp. The durability of railway-sleepers is influenced by :—the consistency and nature of the soil, the nature of the locality as regards free currents of air or the reverse, whether the sleepers are on cuttings or embankments, on cold or hot aspects, and whether the railway-traffic over them is considerable or not.

[In India, wherever the passing of trains is frequent and regular, white ants are not to be feared for deodar sleepers, but they freely destroy them in rarely used sidings or when stacked in depots.—Tr.]

Sleepers usually commence decaying at the top, and from places where bark or sapwood has not been removed. More will be said about them further on. Wood used on the ground for forest tramways, sledge-roads and slides, is evidently as subject to decay as railway-sleepers.

(e) **Places with little Circulation of Air.**—These are frequently very damp, and if they are also warm, as in cellars, underground vaults, stables, engine-rooms, work-rooms, and crowded and badly ventilated human dwellings where clothes are dried and little attention paid to cleanliness, then the wooden fittings of such places cannot be very durable.

Wood used as mining-props is under similar conditions, and hardly anywhere is such a quantity of wood rapidly used-up as in mines, where sprucewood only lasts four to six years.

Even in this case there is a great difference in the durability of the wood under different circumstances, and where props are used in dry mountain mines, and the wood comes in contact with antiseptic substances such as copper and zinc, or in salt mines, woodwork may be very durable. Larchwood has lasted more than sixty years in salt-mines, still remaining almost perfectly sound.

Although in all the above usages of wood, infection by fungi is always the cause of decay, it is damp, warm places where ventilation is ineffective which favour infection by a growth of the fungi. In such places, the presence of the fungi is evidenced by the masses of mycelia produced by *Merulius lacrimans* * (the chief cause of dry-rot) and *Polyporus vaporarius*, which are found on the woodwork of cellars and on beams and floors laid directly on the ground without ventilating spaces below them.

5. *Classification of Woods in Order of Durability.*

From all that has gone before it may be conjectured that it is impossible to attribute fixed periods of durability to certain timbers, and that it is difficult even to classify different timbers approximately according to the absolute powers of durability. If, however, durability is taken as a measure of the duration of a sound condition in timber under the worst possible external circumstances to which it may be exposed when utilized, some attention being paid to its special anatomical structure, timbers may be arranged in the following groups, in order of durability:—

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* *Vide* Hartig's Diseases of Trees, *op. cit.* p. 74.

Very Durable Wood.

Pedunculate oak: Grown in the open in a mild climate and on moist, but not wet soil.

Larch: With well-developed heartwood, highly resinous, not too old, especially when grown in middle Alpine localities (4000 to 5000 feet altitude).

Sessile oak: As durable as pedunculate oak in dry places, but inferior to best larchwood when exposed to damp.

Scotch pine: From old trees, highly resinous, with well-developed, moderate-sized annual zones and well-developed summer-wood. (Baltic red deal.)

Black, or Corsican pine: Of similar nature to the above Scotch pine. Especially valuable for water-pipes or -channels.

Mountain-pine: The erect variety (*Pinus montana* var. *uncinata*, Ramond) is best.

Robinia: Sometimes more durable than oak. (False acacia, or locust.)

Sweet chestnut: More durable in the ground than oak or robinia coppice-wood.

Common elm: From fertile, warm situations; is not liable to be worm-eaten.

Durable Wood.

Ash: Only fit for use under cover, or partially so, as in the case of carts or agricultural implements—then very durable.

Larch: From lowlands, or with little heartwood.

Scotch pine: Rapidly grown, with narrow zones of summer-wood and only moderately resinous.

Spruce: From high altitudes or latitudes, with narrow zones and resinous. (Baltic white deal.)

Silver-fir: About as good as spruce from moderate altitudes; more suited for use under cover.

[Silver-fir is preferred to spruce when both are grown in Britain. —Tr.]

Wood of Little Durability.

Quickly grown and slightly resinous coniferous woods, especially from lowlands, should be used only under cover; they are very perishable when exposed to the air and moisture and in hot sandy soils. **Larchwood** tapped for resin has also little durability.

Beech: Is durable only in dry places and under water; when used in the ground it soon rots; is very subject to be worm-eaten.

Hornbeam: Useful only in dry places under cover.

Sycamore and Maples: Not liable to be worm-eaten; durable only when kept dry.

Alder: Durable under water, otherwise very liable to decay and to be worm-eaten.

Wild cherry: Very liable to be worm-eaten.

Birch: Utilizable for furniture and carriage-panels only when kept dry.

Aspen: Usually durable only when kept dry; but old, reddish aspen-wood is said to be durable.

Lime: Durable, when kept dry, unless it is worm-eaten.

Weymouth-pine: Not durable, and not much prized, even in its native localities. (American white deal.)

Poplars, hazel and **willows**: Only durable when kept dry.

6. *Means of Increasing the Durability of Timber.*

Since durability is of such importance in determining the value of timber, it is evident that the greatest attention should be paid to any means of increasing it. Here, only such means will be considered as the forester can apply, and the question of injecting timber will be deferred till the third part of the book.

It has been already shown how greatly the durability of timber depends on the locality and exposure to light, and this points out the way to produce durable timber by following certain sylvicultural rules.

The greatest possible care should be taken to select the proper species for the locality. Fertile soils and mild climates are necessary for most broad-leaved woods, the amount of light which reaches the crown of the tree being gradually increased, and when they have attained the period of maximum increment, the crowns should be isolated from those of the surrounding trees. For conifers, especially larch, spruce and silver-fir, mountainous regions, cold aspects and density of growth during youth are advisable, and their crowns should be isolated only when their height-growth is nearly completed. By following such rules durable timber will be produced.

Decay of wood owing to fungi can arise only when the wood contains sap or moisture; direct means for increasing the durability of timber must, therefore, consist in keeping it as dry as possible from the time of felling until it is utilized.

Drying timber in the forest is effected by converting the trees into beams, scantling and firewood, and exposing the pieces in airy places, after raising them above the ground. Large timber cannot evidently be much reduced in size; but drying may be expedited by barking the logs and dividing them into halves and shorter pieces. In extraordinary cases, trees may be dried by barking or girdling them before they are felled, or by felling them when in full leaf and converting them after they are fairly dry. Wood never becomes thoroughly dry in the forest, and it is the wood-merchant and not the forester who has to see to the thorough drying of timber.

Special care must be taken of wood which has been killed during the growing-season by insects or fire, or which has become coated with blue mould. Such wood should be prepared, barked and converted at once, if it is to be kept sound.

A high grade of dryness may be secured, in exceptional cases, if a tree is girdled as it stands, or barked up to its crown and left standing till all the moisture in the trunk has been transpired by the foliage. Oaks are sometimes barked in this way in the spring, when the bark is wanted for tanning, and then left standing till the following winter.* Such wood is characterized by exceptional durability, and is in great demand by wheelwrights. Trees intended for use in the Russian navy are barked during the growing-season, and only felled twelve months after, and in order to prevent cracking, the bark is separated from the tree in strips 10 to 12 inches broad, which are carefully left hanging from below the crown of the tree, and then tied round the stem with withes. †

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* [This is done in the Forest of Dean.—Tr.]

† [In Burma, all teak trees marked for felling are girdled, and may not then be felled for two years.—Tr.]

Lanprecht's investigations into the exceptional durability of some beechwood give some idea of the value of another method, in which the tree is felled in full foliage and left with its crown on till the wood is dry, and the wood then converted. He reported that twenty houses are still standing at Lenterode in the Harz Mountains which were built 150 to 200 years ago, and the beech woodwork is still undecayed. The wood was felled whilst the foliage was coming out, and the trees remained with their crowns on till the foliage had developed and become completely dry. The wood was then converted and air-dried.

It may also be remarked that this wood was thoroughly smoke-dried, for there were no chimneys to the houses, and the smoke found its way out, as it could, through the roof.

Similar results were obtained at Vienna in the case of park-palings prepared from beech-trees felled whilst the foliage was coming out, barked, and left lying till the next spring. They lasted seven to eight years, whilst ordinary beech palings last only about a year without decaying.

SECTION XIII.—HEATING-POWER.

By the term **heating-power of wood**, is meant the amount of heat which a certain weight of wood will give out when burned in ordinary stoves. Carbon and hydrogen are the elements of wood which will burn, and when oxidised they pass into the air as carbon dioxide and water, whilst the inorganic elements of wood remain as the ash.

Since the demands for wood-fuel for smelting ores in continental Europe and in the South of England, which were formerly considerable, have been greatly reduced and forest management is therefore principally occupied in producing timber, the heating-power of wood has only a small influence on its value, though the question is still an interesting one.

It is a fact that thoroughly lignified woody tissue has the same heating-power for all species of trees, but the varying forms of tissues found in the different species, the addition of resin and other materials, and of water in varying quantity after the wood has been air-dried, cause different woods to have different heating-powers. The fact that the specific gravity of woody substance is the same for all species of trees, and the experiments as to its heating-power made by Brix, attest its equal heating-power in all cases. The circumstances which affect the heating-powers of the different woods will therefore be considered here.

1. *The Specific Gravity of Wood.*

The heating-power is usually proportional to the amount of solid woody substance, and [*unless, as in certain Indian woods, mineral matter is deposited in the lumina of the vessels.*—Tr.] this is directly proportional to the specific gravity of the wood; so that for a given volume, heavy woods give out more heat than light woods. This is not, however, always the case, and it cannot, therefore, be laid-down as a general rule that the heating-power of wood is proportional to its specific gravity; there are exceptions to this rule which may be explained, partly, by the amount of mineral matter some woods contain, partly, by the fact that wood of any species used for burning is frequently of a different quality to that used for determining its specific gravity, and also owing to the varying amount of resin contained in different woods.

Oakwood forms a well-known exception to this rule, for although it is usually heavier than the wood of beech, birch, and maple, it possesses less heating-power than these woods. It should, however, be noted that we use only inferior qualities of oakwood for burning, good oak being always used for timber. The specific gravity of oakwood is, however, always calculated for perfectly sound wood, and varies between 0·53 and 1·05, showing differences up to 100 per cent., so that much oakwood is really lighter than the above-named woods, which may explain the apparent anomaly.

[In the W. Himalayas, the best fuel is supplied by the heavy wood of the evergreen oaks, *Q. Ilex, semicarpifolia, dilatata*, &c., the maximum weights of which per cubic foot are given in Gamble's Manual of Indian Timbers as 68, 54, and 61 lbs. corresponding to specific gravities of 1·08, ·86 and ·98.—Tr.]

Although the average specific gravity of the different species of woods is no conclusive guide to their heating-power, it may be affirmed that the heating-power of wood of the same species is proportional to its specific gravity, so that heavy oakwood produces more heat than lighter oakwood, and so on. Those parts of a tree, therefore, which have a higher specific gravity also possess greater heating-powers. Hence the heavy heartwood of trees is more heating than the sapwood, and rootwood is less heating than wood from the stem, with the exception of the highly resinous rootwood of some conifers.

Since the heating-power of woods is greatly influenced by their specific gravity, all local circumstances which increase the specific gravity of wood will also increase its heating-power. Thus, independently of the nature of the soil, the amount of light which affects the rate of growth and density of the wood of a tree will increase its heating-power; so that the broad-leaved trees, which attain the best quality in this respect, are those grown on southerly aspects and in fairly open woods, or with perfectly isolated crowns, and not those growing on northerly aspects and in dense woods.

2. *The Amount of Water in the Wood.*

As long as the wood is not perfectly dry, it cannot, when burning, produce its greatest possible heating effect, as much of the heat is used for expelling the water in the form of vapour. This is a matter of everyday occurrence, and it is clear that splitting wood intended for fuel into small pieces and letting it lie in the forest in airy places to dry, must increase the heating power of any wood.

Wood felled during spring or summer, and dried in the forest at the warmest time of the year, is best in this respect. Whenever it is intended to burn the wood as soon as possible after felling, summer is the best season for the purpose; but otherwise the season of felling has no effect on the heating-power of wood. The anatomical structure of the wood also influences the rate at which it dries, as soft and porous wood may be dried more quickly and more thoroughly than denser wood.

The influence the state of dryness of wood has on its heating power is clearly shown in the case of barked oakwood, for although oakwood, as a rule, burns slowly, barked oak coppice-shoots, when thoroughly dry, burn as rapidly as the lightest coniferous wood, and are therefore in great demand for baking, tile-making, and other trades where a quick heat is required.

Nördlinger states that when wood contains 45 per cent. of moisture, it loses half its utilizable heating-power; many woods in winter contain up to 60 per cent. of moisture, and when burned green, only exert one-fifth of their heating-power. The difference between combustibility and heating-power in the green or dry state is not the same for all woods; conifers, when burned in the green state, give out relatively more heat than green broad-leaved wood, chiefly owing to the resin they contain, and among broad-leaved trees, alder and birch give out most heat when burned green. [Silver-fir branches with the needles on contain so much turpentine that a fire can be made from them when freshly cut from the tree.—Tr.] It has often been imagined that wood which has been floated for some time loses a considerable degree of its heating-power, because it leaves somewhat less ashes than unfloated wood. This circumstance, however, can have no influence on its heating-power, and recent investigations have proved that floatage is not appreciably prejudicial to the heating-power of wood, provided it is thoroughly and rapidly dried when landed. This latter condition is frequently not secured, but the wood is often piled together in heaps at the wood-depots, which are not so arranged as to afford thorough ventilation, and therefore the wood does not dry quickly enough. It is owing to this fact that firewood brought from the forest by land-transport is often preferred for heating purposes to floated wood.*

Steaming and boiling wood does not impair its heating-power, provided the wood be thoroughly dried before being burned.

3. *Anatomical Structure.*

The effect of the anatomical structure of the wood, independently of its influence on the drying and density of the wood, is also important, owing to the fact that the substance of porous woods is more in contact with the oxygen of the air than that of dense compact woods. Porous woods, therefore, burn more quickly and more completely than dense woods, or, in common parlance, light woods give a quicker fire, and heavy woods a more lasting one. Hence it follows that by burning equal weights of dry porous wood, a more intense heat is produced than with heavier woods. The heating apparatus of houses is usually of such a construction that, after lighting the fire, a certain interval of time must elapse before a room is thoroughly heated. If the development of heat is then very rapid, much of it passes uselessly up the chimney, as the stove is not capable of storing the heat so rapidly. Thus softwoods waste much of their heat when used for heating rooms. In other cases, such as in bakers' ovens, brick- and lime-kilns, the same amount of preliminary heat is not lost, but a rapid intense heat is required, and for these purposes light woods are most suitable. [Thus, wood from Scotch pine thinnings is in great demand by the Paris bakers.—Tr.]

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* Brix found that 1 lb. floated beechwood heated 4·6 lbs. of water from 32° into steam, and that 1 lb. of unfloated beechwood heated 4·4 lbs. of water to the same extent.

The degree of reduction in size to which wood has been subjected has a similar influence to that of its porosity. A piece of wood reduced by a plane into thin shavings is a thousandfold more in contact with the oxygen of the air than the entire piece, so that the burning of the shavings would be much more rapid and more complete than that of the latter, and the intensity of the heat given out much greater. There is, however, a limit to the advantages of subdivision of wood in this respect, for sawdust merely smoulders, and scarcely emits any flame, when burned.

4. *Amount of Resin in wood.*

The importance of resin in the heating-power of conifers is well known. Resinous wood always evolves more heat than wood poor in resin, as the latter adds so much more carbon to the woody substance.

Old Scotch pinewood, the roots of Scotch pine, mountain pinewood, the lower part of larch-trees, which often contain concretions of resin, portions of the lower part of the stem of spruce-trees where the bark has been injured and which have become encrusted with resin, and resinous old branches of the spruce are, therefore, remarkable for their great heating-power.

5. *Soundness.*

The soundness of wood also considerably influences its heating-power; rotten wood has probably lost at least half of its woody substance, owing to the ravages of fungi, and has a light specific gravity and very little heating-power.

Since, as a rule, young wood is sounder than old wood, firewood from young broad-leaved trees has usually greater heating power than when taken from old trees. It appears that when wood rots, it first loses its hydrogen, for fallen dead wood burns with a very slight flame. Even when perfectly sound, young broad-leaved wood, and especially that of the beech, has a greater heating-power than old wood, and especially than very old wood.

In the case of conifers, as the amount of resin they contain, especially in the case of pines, varies with the age of the tree, old coniferous wood generally has a greater heating-power than young coniferous wood.

6. *Determination of Heating-Power.*

Attempts have often been made to ascertain by experiment the exact heating-power of the different woody species, and two modes of measuring it have been devised, the former **physical**, and the latter **chemical**.

The **physical method** for measuring the heating-power of a wood, consists in heating a boiler with the wood to be experimented on, and ascertaining how many unit-weights of water at 0° C. can be changed into steam by a unit-weight of the wood.

The two elder Hartigs have experimented in this manner with equal volumes of wood, and have found, taking the heating power of the stem of beech as 1:—

100 years old	ashwood	1·44
120 ,,	very resinous Scotch pinewood	1·09
	Robinia (stem)	1·05
100 years old	hornbeam (stem)	1·05
108 ,,	sycamore (stem)	1·03
25 ,,	beech-poles	1·10

50-80 years old split beech	1·04
120-160 ,, beech (stem)	1·00
100 ,, birch (stem)	0·96
120 ,, oak (stem)	0·94
70 ,, larch (stem)	0·82
100 ,, elm (stem)	0·79
100 ,, spruce (stem)	0·76
100 ,, lime (stem)	0·69
120 ,, silver-fir (stem)	0·67
Sweet chestnut wood	0·65
40 years old alder (stem)	0·59
Black poplar and aspen	0·58
28 years old willow	0·48
40 ,, pyramidal poplar	0·47

The following results obtained by Brix show how many lbs. of water at 0° C. may be converted into steam by burning 1 lb. of each of the following woods :—

	Dry wood.	Wood with 15 % water.
Scotch pine (old trees)	5·11	4·19
,, ,, (young trees)	4·68	3·83
Alder	4·67	3·82
Birch	4·59	3·75
Oak	4·58	3·74
Beech	4·54	3·63
Hornbeam	4·48	3·66

These figures show that the amount of woody substance in a wood is the chief factor in determining its heating-power.

The chemical way of deciding as to the heating-powers of woods consists either in an elementary analysis of the wood, and ascertaining how much oxygen is required for converting all the carbon and hydrogen it contains into carbon-dioxide and water; or, this amount of oxygen may be determined by burning the wood in a closed retort with a metallic oxide (red-lead), and ascertaining how much oxygen has thus been used.

A calculation of the average heating-power of different fire-woods by comparing their prices forms no absolute criterion of their heating effect, for many other factors come into the question.

The average ratios of the heating-powers of coal, lignite, and wood may be placed as the figures 2·6 : 2·14 : 0·5. The results of the physical experiments, even more those of the chemical experiments, as regards the heating-power of wood are of doubtful value, contradicting as they do every-day experience, and average results taken from many repeated experiments are therefore desirable. Even were the exact heating-power of the woods to be correctly determined, these results would only be of limited use in actual practice, where the practical heating-power is always found to be much less than theory states it to be, and the loss of theoretical heating-power varies with the different stoves used. This loss is chiefly due to the defects of ordinary stoves as compared with those used for determining the heating-power of combustibles, and the absence in ordinary use of precautions taken in experimental burning. The loss of heat which escapes with the varying draughts of air up the chimneys also varies greatly, and so does the dampness of the wood actually used for fuel. As a matter of fact about half the heating-power of combustibles is lost owing to the way in which they are burned.

The groups below represent the relative heating-powers of equal volumes of different woods, arranged according to common experience by burning them in stoves used for heating rooms.

i. **Best heating Woods.**—Hornbeam, beech, birch, Turkey-oak, mountain-pine from high altitudes, robinia, old resinous Scotch pine, black pine.

ii. **Good heating Woods.**—Sycamore, ash, common elm, resinous birch, ordinary Scotch pine, oak.

iii. **Moderately heating Woods.**—Wych-elm, spruce and silver-fir, sweet chestnut, Cembran pine.

iv. **Badly heating Woods.**—Weymouth-pine, lime, alder, fallen oak-branches, aspen, poplar, willow.

Woods vary also in the manner with which they burn ; some give out much smoke and soot, as resinous coniferous wood

(Scotch pinewood gives more soot than sprucewood), beech, &c.; others less, such as softwood broad-leaved trees, especially alder and birch.

Other woods crackle and send out sparks, owing to the air they contain, as woods of the sweet chestnut, larch, spruce and oak; others to a less degree, as those of Scotch pine, silver-fir and aspen; whilst some woods burn without any crepitation, as those of hornbeam, birch, alder, &c.

CHAPTER II.

INDUSTRIAL USES OF WOOD.

There are few raw materials which possess such extensive powers of adaptability and are so largely used for industrial purposes as wood. A casual inspection of the interior of any building is sufficient to convince one of this.

Wood may be classified according to the manner in which it is used, as **timber** and **firewood.** In timber the dimensions and shape of a tree and its individual technical properties are of paramount importance, and decide the purpose for which it can be used ; as regards firewood, however, they are of little importance, for wood unfit for any other purpose may at any rate be used for fuel.

Subdivision I.—Timber.

SECTION I.—THE DIFFERENT CLASSES OF CONVERTED TIMBER.

1. *General Account.*

The demands on timber are as varied as the kinds of timber available. In considering merely the woods used in the construction of buildings, furniture, implements, tools, and the innumerable articles of convenience, art and comfort, it will be readily perceived that nearly every object requires a special kind of wood. If, therefore, a forest is to be worked intensively, so as to yield the highest possible revenue, it should produce wood which may be used to the greatest advantage, or, in other words, which is most valuable.

In order that the produce of a forest may be of this nature, the forester should possess a thorough knowledge of the special requirements of industries using wood, which is too much to expect from him. To a certain extent, however, this knowledge is indispensable, especially as regards those industries which obtain their wood directly from the forest, and require it in large quantities.

It is true that iron competes more and more with wood for certain purposes—as for shipbuilding, agricultural implements, water-pipes, telegraph-posts and railway-sleepers, where it has been largely substituted for wood; in mines, iron rails and props are used; in the construction of large bridges, woodwork is entirely dispensed with, and iron instead of wooden pillars are used where vertical support is required to a building. Even in numerous small articles iron has been substituted for wood. Yet with the constant increase in human requirements, hundreds of new uses for wood are found, and the demands for high-class timber therefore constantly increase whilst the area of the forests decreases, so that the supply of this valuable material tends to diminish.*

The timber required for various industrial purposes does not in many cases pass directly from the woodman to the artisan, but generally through the intervention of a middleman, the timber-merchant, who converts rough timber into pieces of dimensions suitable for the requirements of the various industries. In this intermediate state it is termed **converted or marketable timber.**

Timber may be classified according to its form, adaptability, and mode of conversion, and this classification naturally precedes the account of the different wood-industries. Thus, **logs** may be distinguished from **sawn,** or **cloven** timber.

2. *Logs.*

Logs are pieces of timber which retain the full thickness of the stem, but may be more or less shortened. They are further distinguished as **round logs.** and **balks,** which have been **squared,** or are of rough prismatic shape, and are also termed **sided timber.**

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* [A paper was written in the Revue des Eaux et Forêts, December, 1894, showing that in Britain, whilst the production of iron is as great as in all the rest of Europe, yet the imports of timber have risen, between 1860 and 1890, by 168 per cent.—Tr.]

(a) Thus, **timber in the round** is the part of a stem which has been merely barked, and may be used directly as piles, masts and spars, wheel-hubs, scaffolding-poles, pillars, anvil-stocks, telegraph-posts, hop-poles, or, when bored, for water-pipes.

(b) **Balks** are used as beams in the construction of houses, bridges or ships, being logs roughly squared either with the axe or saw. If not quite square, they are termed **waney** (fig. 24, *o, p, q, r, s, t, u, v*), **wanes** being the natural surface of the timber, and **panes** the flat, hewn or sawn surfaces from which **side-pieces** have been removed.

FIG. 24.

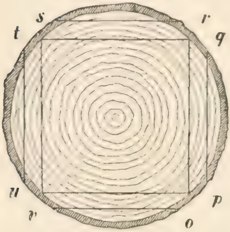
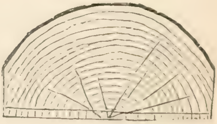


FIG. 25.



In the case of waney balks, for which rarely more than two-thirds of the trunk are utilized, the waste is about 12 to 15 per cent. of the whole, while, when the timber is square, the loss is about 27 per cent.

Boles about 60 feet long and of about 8½ inches mid-diameter, corresponding to 12 inches diameter chest-high (4½ feet from the ground), are commonly used for balks.

(c) **Round oakwood** is sometimes split through the centre into **half-balks**, with a section as shown in fig. 25.

These half-balks are met with in the Baltic oak-trade and in the case of oak from the Spessart, and are used in cabinet-making and joiners' work.

Quarter-balks (*bois de quartier*), are commonly produced in France by sawing two cuts at right angles to one another through the heart of a tree.

3. *Sawn Timber.*

[Various methods of sawing timber are shown in figs. 26 to 29, the best sawn pieces are obtained by cutting as much as possible in the direction of the medullary rays, as wood has a better appearance (silver grain), and stands friction better in this way.—Tr.]

Scantlings, battens and planking, comprise the different forms of timber after the stem has received several saw-cuts lengthwise. Naturally, in these forms of converted timber the full diameter of the stem is no longer retained, except sometimes in one direction, and the length of the pieces is generally of greater importance than their breadth ; it is chiefly large trees (16 inches and more in mid-diameter) which are most usually converted

Fig. 26.*

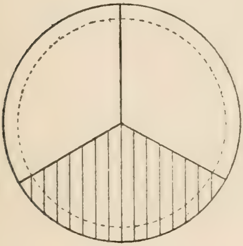


Fig. 27.

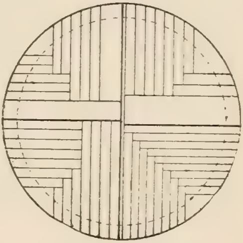


Fig. 28.

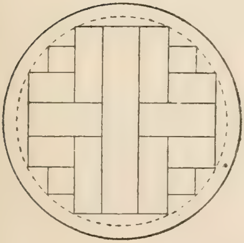
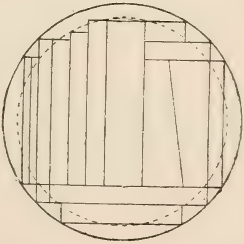


Fig. 29.



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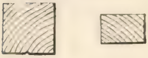
* [Figs. 26 to 29 are after Boppe.—Tr.]

into planks and scantling, and the following kinds are commonly known in the timber-trade :—

(a) Pieces Square, or nearly so, in Section. (Fig. 30.)

i. **Scantlings** may be 8 to 20 feet long, and in section 4 inches by 5 inches, up to 9 inches by 9 inches ; sawn from logs and beams, of 5 to 10 inches mid-diameter and 8 to 20 feet long, also from planks. They are used for supporting floors and roofs, for door-posts, gates, &c.

Fig. 30.



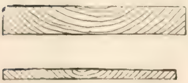
ii. **Battens,** or small scantlings, may be 8 to 20 feet long, and in section 4 inches by ¾-inch, up to 7 inches by 3 inches. They are used for door- and window-frames, &c.

iii. **Laths** are made by sawing up planks, and are 6 to 20 feet long, and in section 2 inches by ½-inch, up to 4 inches by 1 inch. They are used in supporting tiles, slates and ceilings, also espaliers, vines, &c. ; they are frequently split instead of being sawn. Those for ceilings may be sold even when 1 foot or 2 feet long.

(b) Pieces in which the Breadth is much Greater than the Thickness.

i. **Planks** are cut right through the stem, and are usually 10 to 20 feet in length, and 10 to 18 inches by 2 to 6 inches in section. (Fig. 31.)

Fig. 31.



[In the case of oakwood such planks take at least one year for every inch of thickness for seasoning, and they are kept in stock by timber-merchants and used for all kinds of purposes, frequently after being further reduced in size. Railway-sleepers are comprised under this class, their dimensions will be given further on.—Tr.]

ii. **Boards and deals,** under 2 inches in thickness, usually varying from ½ inch to 1¾ inches, and of various lengths, but generally from 10 to 20 feet long, and 5½ inches to 1 foot broad, the usual breadth being 8 inches to 1 foot. They are used for floors, door-panels, cabinet-making, &c

4. *Cloven Timber.*

Cloven timber comprises all those sorts of timber in which the wood is split, or cloven, along the direction of the fibres; it comprises staves for casks, park-palings, laths, shingles for roofing, spokes for wheels, rungs for ladders, hurdle-wood, &c. This class of wood is characterised by the fact that the fibres not being severed, the wood preserves its natural elasticity and strength, and is much less permeable by liquids, and less liable to warp and crack than sawn timber. The work of cleaving timber is also more expeditious, and requires simpler implements than sawing, and there is scarcely any waste of material involved.

In cleaving wood, it is advisable, whenever possible, to work from the centre of the piece of wood outwards.

SECTION II.—TIMBER USED IN SUPERSTRUCTURES.

(a) **Different Kinds of Superstructure.**—The term **superstructure** includes all parts of buildings which are above ground or water, so that the timber used in their construction may be exposed to the external air and to atmospheric influences, but not to moisture from the soil or in water-courses. Building-timber may be distinguished into **sawn timber** (beams, planks and scantlings), which is fitted by a **carpenter**, and **planed timber** used for floors, doors and windows, and fitted by a **joiner.**

According to the demands on the durability, strength, beauty, &c. of the timber used, and to its local value, different modes of building are employed, some of which use timber in large quantities, and others much more sparingly.

These modes of building may be distinguished by the nature of the walls erected. Thus, **block-houses,** or **log-huts,** have entirely wooden walls; the **wooden framework** sometimes employed for the walls of houses may be filled-in with planks, bricks, or lath and plaster; the walls of other superstructures are built of **mud, stone,** or **brick masonry.**

In the case of **log-huts,** the walls of the whole building are made of round logs or squared balks, the necessary firmness of the building being secured by dovetailing their ends into beams placed at right angles to them. Log-huts are still used in the Alps, and in countries like America or Australia, where timber is still abundant. A higher class of houses is built with a complete wooden framework of beams and scantling, dovetailed and riveted together, and the interspaces are afterwards covered with planks, or filled-in with lath and plaster, or with rubble- or brick-masonry. Houses with a wooden framework filled-in with masonry are termed **half-timbered**. In the Middle Ages nearly all houses, and even large edifices, were built with a wooden framework, owing to the abundance of wood; at present this mode of construction is limited to woodland districts, and especially to Switzerland and the Black Forest. Its use is becoming more restricted in Europe, as communications improve, and stone- or brick-masonry takes its place.

[In countries like Japan or Assam where earthquakes are frequent, this mode of building is far safer than masonry, the interspaces between the wood being filled-in with reeds or bamboos plastered over. In the event of an earthquake, the whole house holds together and the danger of falling masonry is avoided. Owing to the malarious nature of the country in Assam, houses are frequently raised above the ground on piles.—Tr.]

Brick- or stone-masonry is the best material for the walls of buildings, and is at present most usually adopted [though in fairly dry countries, such as the N.W. of India, walls, and even roofs, are frequently made of mud.—Tr.]. In all these cases the minimum amount of wood is used, and chiefly for doors and window-frames, for the flooring and wainscoting of the different stories (though even this may be partly made of stone and cement, supported by iron girders), and for staircases and roofing.

Wooden scaffolding used during the construction of buildings of all kinds also requires a large quantity of round timber and some planking, and work-sheds and other similar constructions are usually made with a wooden framework.

Beams, scantling, planks, &c., and round timber for scaffolding, are the usual forms in which wood is used in superstructures, and the properties which timber should possess for use in superstructures may be considered under the headings—**shape and dimensions, strength, durability** and **weight**.

(b) **Shape and Dimensions of Timber Used.**—Although in the construction of staircases and of half-timbered houses, curved wood is admissible, the carpenter requires straight, cylindrical logs for most of his pieces. The length and diameter of the pieces depend, of course, on the size of the building for which they are required, but the pieces used for any particular building will be classed in uniform sizes. They are seldom thinner at centre than 4½ to 6 inches, or thicker than 1 foot. The usual transverse dimensions of squared timber for constructions is from 7 to 9 inches, for which, allowing for bark and sapwood and average cylindrical shape, trees measuring 1 foot to 14 inches in diameter are required. As regards length, the carpenter usually prefers the longest pieces, provided the falling-off in cylindrical shape is not too great.

(c) **Strength of Material.**—Timber is subjected to loads which when applied transversely to the length of the pieces tend to cross-break them. In such cases, the timber serves the purpose of a beam, as for instance, the joists for supporting floors and rafters for roofs.

The strength to resist bending is proportional to the width of the beam and the square of its depth. Two beams of half width have the same strength as one of whole width, but two beams of half depth superposed one on the other have only half the strength of one of whole depth. The greater transverse thickness therefore should be placed in the direction in which the load is applied. In order to provide sufficient stiffness as well as strength, the depth of beams, &c., is made from $\frac{1}{12}$th (in short beams) to $\frac{1}{20}$th of the length or span (in beams 20 feet long), and to give lateral stiffness, the width is about $\frac{1}{3}$rd of the depth in short beams, and $\frac{1}{4}$th in long beams. For spans exceeding 20 feet, iron and steel girders are generally used.

When the load is applied in the direction of the length of the piece of timber, the latter acts as a strut or column, when the load thrusts, or as a tie when the load pulls. Timber is very rarely exposed to a strong pull on account of the difficulty of getting secure attachments to the ends of a piece, by merely butting the ends, however, unlimited thrust may be applied. Long struts or columns are liable to yield not by direct crushing, but by cross-breaking due to lateral bending. The thrust which can be safely borne varies from $\frac{1}{4}$ of a ton per square inch of section in struts of a length equal to 8 times their diameter, to one half of that amount when the length is 24 times the diameter.

(d) **Degree of Soundness and Durability.**—All pieces of timber used in constructions must be perfectly sound and sufficiently durable, and in all cases none but thoroughly seasoned timber should be used. Some of the pieces used in buildings are more exposed to decay than others, such as those used for cellars, wash-houses, breweries, stables and other damp places, whilst roofing timber is less endangered.

It is not surprising to find, if green timber be used, that destructive fungi attack the beams, &c., and early repairs are necessitated.

[In countries where white ants abound, only wood which they do not attack should be used in constructions, an exception being made for rafters, when the masonry, or half-timbered walls are secure against the passage of the ants. It is also usual to smear the timber externally with wood-oil, extracted from species of *Dipterocarpus*, which is a great preservative against insects.—Tr.]

(e) **Weight.**—Weight is now-a-days avoided as much as possible, especially in the roofs of buildings, which were formerly made of heavy oakwood. In substituting light coniferous wood instead of oakwood for roofs, fairly durable wood should be used, such as narrow-zoned and not broad-zoned wood—at least, for the principal roof-timbers. The price of this fine-zoned timber is usually considerably higher than the inferior material. Greater ease in construction is also a cause of the preference of light to heavy wood.

[In India, bamboos are largely used for roofing, under thatch they should be at least three years old shoots, and thoroughly soaked in water for a month or two before being used, in order to avoid insect-attacks.—Tr.]

In Europe, the woods of spruce, larch, silver-fir, and Scotch pine, are chiefly used in buildings on account of their lightness and other qualities, and good larchwood is the best material of them all. These woods are straight and strong, and if not grown too quickly, sufficiently durable; they are cheap and easily worked.

Oakwood, formerly considered indispensable for building purposes, is at present much less frequently used, on account of its high price. It should, however, still be preferred in all damp, steamy places, where great demands are made on the durability of a wood.

The spruce is more extensively used in buildings than any other timber, on account of its cheapness and special qualities. Its perfectly straight stem possesses great transverse strength and sufficient durability, and it is light and easily worked. Owing to its greater durability, good larchwood, which possesses all the other qualities of the spruce, is largely used in mountain districts. Black pinewood from the Alps approaches larchwood in value. The Scotch pine also affords excellent building-timber, which is more durable than sprucewood, and is generally preferred for beams. Silver-firwood is very elastic, and yields timber of as large dimensions as any of the above, and it is more cylindrical than sprucewood, on which account it is preferred to it in some districts. In others, it is reported as of limited durability, and liable to be worm-eaten, but is usually preferred to sprucewood in damp places. [It appears doubtful whether builders really distinguish between spruce and silver-fir timber, and local custom frequently prescribes the kind of building-timber which is preferred, irrespective of its other good qualities. Silver-firwood grown in Britain is in higher repute than indigenous sprucewood.—Tr.] Wood of the Weymouth-pine is also used in buildings, but it is considered to possess little durability or strength, and is not much prized in Canada, its original habitat.

The wood of few broad-leaved species, except the oak, are used in buildings. [Chestnut-wood has been reported to have been used in roofing cathedrals in France and England, but Mathieu (*Flore forestière*) states that when the wood of these roofs has been examined by an expert, it has always been found to be of oak.—Tr.] Elmwood affords good building material, but is scarce in Germany, though fairly common in Britain. Aspen-wood, in spite of its little durability, is sometimes used for light roofing spars. Almost any wood may be used to fill in the frame-work of timbered houses, and beech is often employed for this purpose.

Amongst foreign woods, imported from Algeria, Florida, Canada, Australia, &c., chiefly belonging to the species, *Quercus*, *Pinus*, *Abies*, *Taxus*, *Taxodium*, *Cupressus*, *Cedrus*, *&c.*, that of the Pitch pine (*Pinus australis*), on account of its great durability and strength, beauty of grain and comparative cheapness, has been recently in great demand.

[Of Indian woods, the teak, deodar, blue pine (*P. excelsa*) and the sal (*Shorea robusta*) afford some of the best building material, but each province (especially the moister regions of Bengal, Assam, Burma, Bombay and Madras) possesses a few other species yielding durable timber. By far the larger number of Indian trees are greedily devoured by the white ant, however well they may be seasoned, and this greatly restricts the possible selection of timbers to be used for buildings.—Tr.]

Section III.—Timber used on, or in, the Ground.

Woods used in the form of piles for foundations in yielding ground, or to support road-embankments; also woods used in aqueducts, roads, railways or mines, come under this head.

1. *Wood used in Foundations of Buildings.*

Where buildings are constructed on yielding soil, a foundation is frequently made for them by driving piles 8—12 inches in diameter, and 10—16 feet long, into the ground, sometimes in several tiers one above the other, until a firm foundation has been secured. This frequently takes a very large quantity of timber.

Wherever these piles are not completely under water they are extremely liable to rot, owing to the variable moisture in the soil which is not usually sufficient to exclude the air, and to the usually moderate temperature of the soil. Hence the most durable woods are used for this purpose, such as oak and resinous conifers, chiefly larch and Scotch pine.

Wherever the soil is permanently wet, alder-wood may also be used, as it is essential that the piles should be straight. Spruce wood is often used in the absence of better material.

2. *Wooden Water-pipes.*

Although iron water-pipes are everywhere replacing **wooden pipes** for aqueducts, yet in certain well-wooded countries the latter are still used, and for this purpose the best Scotch pinewood, larchwood, and black pinewood are most suitable.

These woods usually last 8—10 years, if they are laid at a proper depth below the surface of the soil, somewhat over 2 feet, where frost and heat do not affect them.

Failing these, woods of spruce, silver-fir, and alder may be used. Oakwood gives the water a bad taste, and is too expensive for the purpose, and other woods are not sufficiently durable. [Deodar-wood is the best to use in the Himalayas for aqueducts. —Tr.] The wood is bored and used quite green, and supplies of wooden pipes must be kept in running water to prevent warping and cracking. It is preferable to keep them in dry sheds than in stagnant water, where spores of fungi get into the tubes and cause premature decay.

Single pipes are 9—16 feet long, as it is difficult to bore them to a greater length. The wall is generally as thick as the bore.

3. *Wood used for Timber Export-Works.*

Wood is also frequently used in forest export-roads, slides, or sledge-roads. Wherever there are extensive coniferous forests, and the local prices of wood are low, large quantities of wood are used for fencing, supporting embankments, culverts, bridges, and for covering swampy ground; all kinds of wood, chiefly coniferous wood, are used.

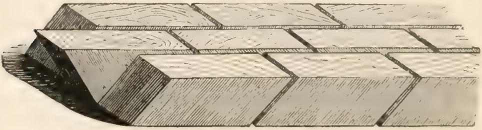
4. *Wooden Paving.*

Wooden paving is now employed in the streets of large cities. [In London, jarrah (*Eucalyptus marginata*) and kari (*E. diversicolor*) are now largely used for this purpose, and doubtless Pyngado (*Xylia dolabriformis*), and other heavy Indian woods might be used with advantage.—Tr.] Among European species the hardwoods, beech, oak, and elm are best, but owing to its cheapness Scotch pinewood is also largely used, and has proved to be as durable for this purpose as Pitch pine.

Injected wood is generally used, and zinc-chloride is said to have given better results in this respect than creosote. The wood is used either in rhombs, or rectangular prisms, placed on a slightly arched dry layer of concrete, molten asphalt being poured between the blocks, which are afterwards covered with a layer of fine gravel and well rolled.

Wooden street-paving has proved as durable as asphalt, and does not exercise so much wear and tear on the shoes of horses, or the tyres of vehicles; it also affords a firmer foothold to the horses, and makes less noise than stone-paving. The blocks of wood are 6—12 inches long, 3 inches broad and 6—7 inches thick; when rectangular they are placed endways, and when rhombic, as in the figure. Blocks of Scotch (red) pine and other wood are also used for the flooring of stables, threshing-floors, or outdoor staircases.

FIG. 32.

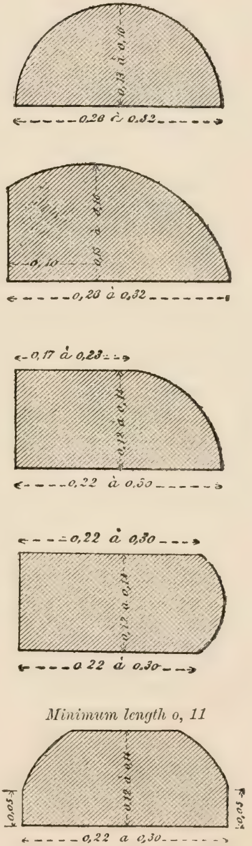


5. *Railway-Sleepers.*

Up to the present time railways have made great demands on forests, chiefly for **railway-sleepers,** or **ties**, as they are termed in America.

[The dimensions of railway-sleepers vary in different countries, in England being 9 feet × 10 inches × 5 inches, or 3⅛ cubic feet; eleven of these sleepers are used for 30 feet of line, being about 2¾ feet apart, but are further apart towards the centre of the rails and closer near the joints. Each red pine sleeper is saturated with 2½ gallons of creosote, which is forced into the sleepers under pressure. The breadth of gauge between the rails is 4 feet 8½ inches, which with the width of the rails, 3½ inches, makes up 5 feet, the ordinary width apart of the wheels of a cart. In France great latitude is allowed in specifications of sleepers, as shown in fig. 33.

Fig. 33.



(Dimensions in meters.)
Different sections of Railway-Sleepers used in France. (After Boppe.)

In India, the ordinary gauge, termed the broad-gauge, is 5½ feet; and the meter-gauge, 3 feet 3⅜ inches, corresponding to sleepers 10 feet × 12 inches × 6 inches or 9½ feet × 10 inches × 5 inches, and 8 feet × 8 inches × 4½ inches respectively.

The rails are placed on steel chairs fastened to the sleepers by iron spikes, oak trenails or both, and it is essential that there shall be no bad knots on the sleepers just where the chairs are fixed to them.—Tr.]

The yearly requirements in new railway-sleepers for Europe is estimated at 30,000,000 cubic meters (1,060,000,000 cubic feet) or 21,200,000 loads of wood, the annual produce of about 20,000,000 acres of forest. Steel and iron sleepers are, however, to some extent replacing wooden ones; and in 1892, 15 per cent. of the 26,800 miles of German railways were laid on metals, whilst the number of wooden sleepers used was as follows :—

Oak	1,427,165
Coniferous	1,420,154
Beech	233,858
	3,081,177

When sawing logs into railway-sleepers, it is evident that the waste should be reduced to a minimum, and the following facts should be noted :—

	Diameter of log at small end.
For 1 sleeper	10 inches
,, 2 sleepers	14 ,,
,, 3 ,,	17 ,,
,, 4 ,,	19 ,,

Larger timber, especially of oak, is generally too valuable to be converted into sleepers, and on the Continent usually only third-class oak timber is thus used. There is between 30 and 40 per cent. of waste.

Up to a recent period oakwood was considered essential for railway-sleepers, on account of its durability, extending to 10–16 years. Highly resinous narrow-zoned larch sleepers last 10 years, and those of Scotch pinewood similarly characterised last 7–9 years, whilst other woods unless injected were formerly hardly used at all. As, however, the supplies of oakwood in Europe are quite insufficient for the supply of railway-sleepers, and the price of good oak timber is very high, after sufficient experience of the advantage of injecting timber, Scotch pine, spruce and beech have been largely used.

Sleepers injected with various substances (*vide* p. 659) have the following durability :—

Oak	19·5 — 25·0 years
Scotch pine	13·9 — 22·8 ,,
Spruce	6·6 — 9·6 ,,
,, (in Bavaria)	8·0 — 12·0 ,,
Beech	13·0 — 17·8 ,,

Young oakwood, owing to its greater density, is more suitable for railway-sleepers than old timber. The fact that many oak sleepers have not proved durable, is due to their being taken from the worst class of oak timber, which is frequently unsound. As regards durability, much depends on the ballast, and the nature of the soil and climate. If these factors are favourable, they may allow an uninjected sleeper made of wood of otherwise little durability to last for a long time.

Attempts to replace wooden sleepers by stone ones were quickly abandoned on account of the unsuitability of the latter. Iron and steel sleepers are now, however, largely used, chiefly in the trough-shaped form, the old "pot" form not having been satisfactory. This substitution of iron for wood is due to the large quantity of iron available and to its great durability. The chief objection to the iron sleepers consists in the change in the molecules of iron, due to the action of the traffic, which renders the metal brittle. Another objection lies in the great cost of iron sleepers. [In India the saline nature of the soil is often prejudicial to metal sleepers.—Tr.] On the whole, wooden sleepers are preferable if they can be procured. It is, therefore, the duty of the forester to produce as many oak sleepers as possible, and to favour their impregnation, if the field is not to be abandoned to iron. Attention in Germany should also be directed to impregnating good young beechwood, of which only 1 per cent. of the sleepers are at present made, although such sleepers are largely used in France.

6. *Wood used in Forts.*

Pallisades in fortresses are made of all kinds of wood, chiefly coniferous. Platforms for guns and other parts of forts are made of all kinds of wood, chiefly oak and Scotch pine.

7. *Mining Timber.*

In spite of the large use of iron in supporting mine-galleries, large quantities of wood are also used for this purpose, as well as for lining shafts in pumping-works, &c. Wood used in mines is exposed to damp air, damp and frequently wet soil, and, in the deeper mines, to a constant degree of comparatively high temperature. Every circumstance therefore tends to favour the decomposition of the wood, and it seldom lasts more than 4–6 years. If the demands were not so considerable, none but the most durable oakwood ought to be used. It is, however, more economical to use the wood which is locally most easily procurable, and this is chiefly coniferous, of which larchwood is most durable, and then resinous Scotch pinewood, but in Germany even sprucewood is sometimes used. Among broad-leaved trees beech is most commonly used, and largely so when shod with steel, as stamping hammers for pounding minerals.

With the exception of beams used vertically, dovetailed together in shafts, ladder-wood, and some other pieces, wood for mines is chiefly required in round logs free from bark. Different forms of sawn wood are also in demand for lining shafts, generally in the form of inferior coniferous boards and planks. Wood may be supplied in full-lengthed logs, which the mining carpenter reduces to the required dimensions, or in the form of **pit-props**, in which the chief bulk of mine timber is comprised, and which vary from three to eight inches in mid-diameter (not less than 2½ inches at the smaller end), and 24 to 30 feet long, and even longer. Only about 15 to 20 per cent. of the mining-props are required in pieces measuring 12 to 16 inches, mid-diameter.

[Scotch pine will yield pit-props when 40 years old, and birch at 25 years, and for British coal-mines over 600,000 tons of Cluster pine are imported annually from Bordeaux, where it is grown and tapped for resin in the extensive forests of the Landes and Gironde. —Tr.]

Wood is put to some other uses where it is subject to similar conditions as wood used in mines; for instance, well-frames, for which purpose resinous coniferous wood, especially that of larch, black pine, and Scotch pine are suitable; also in cellars, for bottle-racks, for which oakwood (or iron) is chiefly used.

Section IV.—Wood used in contact with Water.

1. *Bridges, &c.*

Wood used in watercourses and bridges is under very much the same circumstances as wood in contact with the ground, except that it may be partly or entirely under water. All wooden bridges and works used in connection with them for strengthening the banks of watercourses, sluices, weirs, booms and other timber-catching apparatus on streams used for floating, require pieces of many different shapes. Although iron bridges are now becoming usual even across narrow streams, and roads are replacing water-carriage for timber to a large extent, yet the importance of canals for cheap traffic of heavy goods is being more and more felt, so that very large quantities of timber are required in hydraulic engineering.

Timber thus used is greatly exposed to decay, so that oakwood and resinous wood of larch and Scotch pine are generally employed for these purposes.

In the case of works for floating timber, it would be highly advantageous were the best wood used, but owing to its abundance in mountainous districts, and to the great cost of oak and larch, sprucewood is usually employed, although its durability is small.

Water-wheels for flour and sawmills and other purposes should also be made of oakwood, but are usually made of the wood of Scotch pine, larch or even spruce.

Bridges are usually boarded with beech, which gives a smoother surface and is less liable to splinter than oak or coniferous wood, but the considerable amount of warping and shrinking of beechwood must be allowed for.

The axle of a water-wheel must be thoroughly sound and free from flaws, it is seldom more than 18 feet long, and is usually made of the wood of oak, larch, Scotch pine, spruce or even beech.

The diameter of the axle does not depend entirely on the size of the wheel, and the amount of the work to be done, but also according as the spokes of the wheels are dovetailed into the axle, or fastened to it tangentially.

Iron wheel-axles rest on beech or hornbeam bearings, which are supported by a strong framework of oak, &c.

2. *Fascines.*

Fascines are often used to support banks, a fascine being a bundle of young stool-shoots of different species and dimensions. Their usual length is 10–12 feet, the height to which the coppice grows, and they should measure 12 inches in diameter at the larger end. Fascines are used tranversely to the bank of the stream, and long thin fascines, made of the finest available material, only 5 or 6 inches thick, but 24 to 50 feet long, which are bound with withes at intervals of ten inches are pegged down over them. Another kind of fascine is 12—20 feet long and 24—36 inches across, filled with heavy stones, and sunk alongside the bank in deeper water where the stream is strong. Quick-growing trees and shrubs with five to six years' rotation, especially willows,* are used for fascines; also buckthorn, viburnum, alder, hazel, poplars, ash, black- and white-thorn.

The best time for felling coppice for fascines is in March, just before the spring-shoots come out. This is satisfactory alike to the engineer and the forester, as the former gets the material when it is richest in sap and therefore heaviest, whilst the latter cuts the coppice just before sprouting, which secures a good reproduction from the stools.

For wattle-fences, duck-decoys, &c., osier-willows yield the best material.

SECTION V.—WOOD USED IN MACHINERY.

Iron and steel are fast replacing wood in machinery, and it is only in purely agricultural districts that any machines are still wholly made of wood. It is therefore only parts of machinery, chiefly the frame-work, bearings and fixings of heavy machinery, that are made of wood. Wood is chiefly used in sawmills, flour-mills, &c., and in machinery for driving wooden stamping-hammers. Even in large factories, however, wood is still required; and then generally wood of dense structure is used, which resists shocks and friction.

In all works driven by water-power, the water-wheel is the most important implement, and has been already referred to. In extensive plains, sails of windmills replace the water-wheel; they are always made of coniferous wood, and chiefly of Scotch pinewood of best quality, such as is required for masts of ships, and are sometimes very large. Pieces should tail-off at the small end. Steam-power is however replacing wind-power to a great extent.

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* *Salix fragilis, alba, rubra, amygdalina, viminalis, acuminata,* &c.

As regards the demands for wood for the interior of factories the following short remarks will be made ;—

All wheels are made of iron, but hornbeam and dog-wood are still sometimes used for cogs. In sawmills, the supports of the saw and the bed are chiefly made of coniferous wood, the rollers of the latter are of wood of hornbeam, elm or oak. In flour-mills, except the wheels, most of the fittings, such as the hoppers and meal-bins are made of coniferous wood. The case in which the mill-stones work should be of Scotch pinewood, as free from resin as possible, or of silver-fir wood. All parts of the mill where friction is exerted should be of beech or hornbeam. In oil-mills and stamping-works, hard broad-leaved wood, such as that of beech, hornbeam, oak and ash, is required rather than coniferous wood, and also for pounding troughs in oil, tan, powder and bone-mills.

Stamping-hammers are now usually made of iron, but in mountainous forest districts, many are still of wood bound with iron, and large quantities of beech, birch or hornbeam logs are used for them, in round pieces 8 to 10 inches in diameter and 6–8 feet long. These pieces often require replacing 6 to 8 times in a year. They come constantly in contact with the glowing mass of iron below them, on which water is poured, which causes them to crack in all directions and wear out rapidly.

The anvil-stock below the hammers is made of an oak log at least 3 feet in diameter and 6 feet long, which is bound with iron and let firmly into the ground.

Wood is largely used in all factories for frame-work, work-tables, floors, &c., and after coniferous wood, beechwood in thick planks and scantling is chiefly employed.

SECTION VI.—SHIP- AND BOAT-BUILDING.

1. *General Account.*

In no industry has wood of recent years been more largely replaced by iron than in shipbuilding. It is chiefly the larger men-of-war, steamers, and sailing ships which are built of iron. Iron ships are most resisting to storms, of larger burden, easier to repair and more durable than wooden ships.

As regards the shape, there is a considerable difference between ships intended for the sea, and fresh-water barges: the former are comparatively short compared with their breadth, with keels which run straight from end to end of the ship; whilst all the other lines are of different degrees of curvature.

This curved shape is given to ships by means of ribs, which are partly made by joining different pieces of wood, but also by using curved pieces.

Fresh-water barges have no keels, but a broad flat bottom on which the knee-pieces are fastened at a sharp angle, so that the straight line is much more frequent in their construction than in that of ships. The chief strength in ships consists in the ribs which are very close together, the outer planking being less important; in barges the ribs are much further apart, and the planking is of greater importance.

The demands on wood for ship and boat-building depends on species of wood, its quality, shape and strength.

2. *Species and Quality.*

Oakwood is the principal material used in ship-building, and nearly the whole framework of wooden ships, boats and barges is made of it. All oakwood is not, however, suitable for the purpose; for there is much inferior oakwood which is worse than several other timbers.

Durability and strength are the principal requisites in ship-building timber; and to ensure these qualities in oakwood, only broad-zoned timber should be chosen, with annual zones up to 7 to 8 millimeters, say ⅓ inch, with a narrow zone of fine pores. The wood should be light-coloured rather than dark-coloured when freshly cut: in any case, of uniform colour throughout, as long-fibred as possible, tough and with a strong fresh odour of tannic acid.

Inferior oakwood has narrow annual zones, comparatively broad porous zones and wide pores, is short-fibred and brittle, and darkish coloured, streaky, or reddish in colour and only slightly scented.

It is evident that not only the very best kinds of oak-timber are used in ship-building, the ship-builder knows the parts in the ship where the less valuable qualities may be used; but it is also evident that there is a limit to the use of inferior oakwood in the construction of a ship, and the forester should at any rate be able to recognize the better qualities, and whether the oak-timber his forests produce is fit for ship-building, or not.

It is difficult to decide whether the pedunculate or sessile oak is really preferable; but most of the wood used in ship-yards is pedunculate oak; in Norway, however, that of the sessile oak is preferred. Oakwood from rich soils and mild climates is best, and the countries bordering on the Adriatic sea, Istria and Carinthia, yield the best oak, that from Slavonia, the Spessart and Poland being less suited for ship-building. [English and French oak-timber is also largely used in dock-yards, and French (and Sussex) oakwood is preferred in England.—Tr.]

In the north of Europe, a number of smaller coasting vessels and fishing and river-boats are constructed of coniferous wood. Larchwood is preferred, but spruce and Scotch pinewood are chiefly used, the latter being much more serviceable than spruce. Light boats are also built of the wood of *Salix alba*.

Teakwood (*Tectona grandis*) is at present much more employed in ship-building than oakwood, it scarcely warps at all, is more durable than the latter and does not rust iron nails and bolts. Certain species of *Eucalyptus* from Australia and Tasmania are also used for ship-building. [*Tewart or White Gum (*E. gomphocephala*), Jarrah (*E. diversicolor*), Iron-bark (*E. siderophloia*) and Blue Gum (*E. Globulus*).—Tr.] Mahogany (*Swietenia Mahogani*) is also used and the Pitch pine (*Pinus australis*) for boards; of the American oaks, *Quercus virens* and *Q. alba* are most esteemed. The chief obstacle to the use of oakwood is the tannic acid it contains, which involves rapid rust in all iron with which it is in contact, and consequent decay in the wood. The chief value of several tropical and sub-tropical species of trees for ship-building consists in the absence of tannic acid in their wood.

Next to oakwood, wood of the Scotch pine or red deal is largely used in ship-building, chiefly for masts and rudders. This timber varies in quality much more than oakwood, and the best qualities of red deal are strongly resinous and have narrow annual zones. (*Vide* Plate II.)

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* *Vide* Timber and Timber Trees, by Laslett. 2nd edition. Macmillan & Co. 1894.

All mast- and rudder-wood should be straight and cylindrical, free from knots, elastic and uniformly resinous throughout. The sapwood, which is always trimmed-off, should be narrow, being only $\frac{1}{5}$ to $\frac{1}{4}$ of the diameter in the best woods. The large masts taken from the Hauptsmoor Forest near Bamberg have frequently only 1–2 centimeters (3–6 eighths of an inch) of sapwood, and even this, full of turpentine. Too highly resinous woods are not esteemed, as they are less elastic and strong. At the same time, the annual rings should not be too narrow, and experience proves that a breadth of ring of 0·75 to 2·00 mm. ($\frac{1}{20}$ to $\frac{1}{8}$th of an inch), provided it is continued uniformly to old age, characterises the best sort of mast-wood. As regards colour, Scotch pinewood, of clean, bright, uniformly yellow colour, is preferred.

The best red deal comes from the north, especially the Baltic coasts, Scotland and Norway. The best mastwood comes from Riga, and is superior to all other mastwood in elasticity, strength and durability. Hardly any mastwood of the old excellent quality is now to be had, owing to the prevalence of even-aged woods with forced growth.

The larch from high latitudes, or altitudes, comes next to the Scotch-pine as mastwood, and this species is largely used for masts in the Russian navy, where the northern Ural mountains yield splendid larch-timber. Spruce and silver-fir yield only inferior mast-wood, their timber not being strong enough for the purpose. In the Austrian mercantile navy, however, sprucewood from Carinthia and other provinces is largely used for masts. Spruce masts are also largely used for sailing boats on most of the German rivers.

American and Australian conifers are also used for masts, such as the Douglas-fir, Canadian Weymouth-pine, Kauri (*Dammara australis*) of New Zealand, and pines and larch of Asiatic Russia, all of which come to European dock-yards in increasing quantities.

For the inner lining of ships, besides the woods already mentioned, of which larch and Scotch-pine are largely used for deck-planking, many other species are employed. Injected beechwood is sometimes used, not only for keels, but for the whole framework of ships on the Dalmatian Coast; the wood of elm, maple, lime, &c., and boxwood are used for models.

3. *Permissible Defects.*

All wood used for shipbuilding cannot be entirely free from defects, for if that were the case, sufficient wood would not be obtainable from a large forest district to make a single ship, as old oakwood is seldom perfectly sound.

Wood which, owing to its dimensions, is ranked as first-class, may have small local defects which do not practically weaken the balks. Brown spots and rings at the larger end of a balk, provided they do not penetrate far into the wood, and may be removed by shortening the balk, need not cause it to be rejected. Where small patches of red or white rot and other similar defects occur, which are thoroughly dried and are not expected to extend any further, the decision of the admissibility of the affected wood must be left to an expert.

Large heart-shakes, frost-cracks, twisted fibre, deep-going black and brown marks, rotten places descending from branches, are defects which naturally exclude the timber possessing them from use in shipbuilding.

Shipbuilders as much as possible avoid using any defective timber in new ships, whilst in repairing old ships such material may be more admissible.

4. *Shape and Dimensions.*

All shipbuilding timber is either wood for construction, or mast- or spar-wood.

(a) **Timber used in Construction.**—This comprises curved and long wood.

Curved or compass timber is chiefly used in the framework of ships. As a rule, the curvature should be uniform throughout the piece (fig. 34), or greatest at one-third from one of its ends, and when this is one-third the distance from its larger end (fig. 35), the piece is most valuable. Some of these pieces are thirty to forty feet long. Curved woods are chiefly required which have a **sagitta or camber** of 2·5 and 1·5 centimeters per meter (*i.e.* $\frac{1}{40}$ and $\frac{3}{200}$), but this may be exceeded in certain pieces as in fig. 36. The beams used for supporting the deck are much less curved.

Wood is now artificially bent for shipbuilding, as in certain factories in Hungary, but it is then probably weaker than naturally curved wood.

FIG. 34.

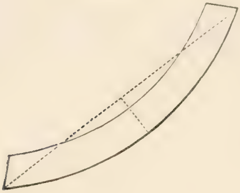


FIG. 35.

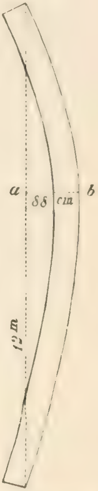


FIG. 36.

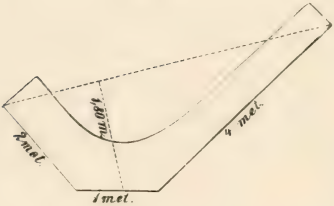
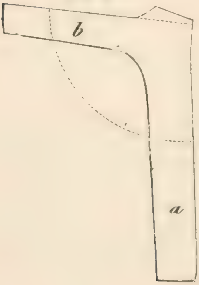


FIG. 37.



Kneed timber is formed where a bough parts from the parent stem as in fig. 37. The branch should accord in its dimensions with the stem, and not be too small when compared with the latter.

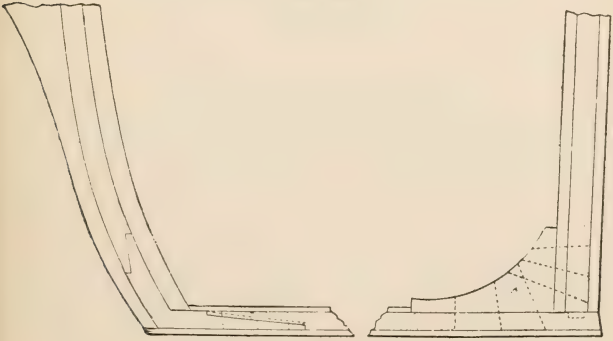
The chief use of **knee-pieces** is in the construction of river-barges; wood of smaller size is then required than for ship-building, and in that case the arm *a*, fig. 37, is much longer than *b*, whilst for ships it is only twice as long. In North Germany, where oak is scarce, large, branchy Scotch pines are used for knees, which would otherwise be fit only for firewood. Such knees last 10 years in barges. Beechwood may also be so used in the interior of vessels. In Saxony use is made of the lower part of a spruce stem with a strong root attached, which may be 15 to 20 feet long, and 7 to 10 inches thick.

It is difficult to give the proper dimensions for compass-timber used in shipbuilding, but the longer and thicker, the more valuable they are; 10 inches diameter, and 15 to 20 feet length represent the minimum dimensions. When used for barges and boats the diameter of knee-pieces may go down to 4 inches.

Long, straight pieces of timber are used for **keels**, but are chiefly sawn into planks for the **inner, or outer, casing of vessels,** and even larger sizes are required than for compass-timber: lengths below 24 to 30 feet, and a diameter of less than a foot at the smaller end, are not permissible. Only in the case of planks for barges are much smaller sizes used.

Figs. 38 and 39 show different sections of a ship where the curved pieces are used.

Fig. 38.

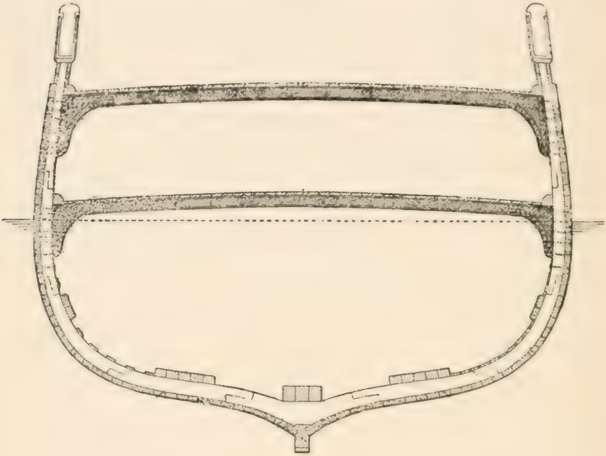


Longitudinal section of a ship. (After Boppe.)

(b) **Mast- and Spar-Wood.**—Wood for masts, booms, and spars should be perfectly straight, as cylindrical as possible, and when required for large ships, of the largest possible dimensions.

First-class masts must measure, free from sapwood, at least 60 to 80 feet in length and be 16 to 20 inches in diameter at the small end, and such masts were formerly procurable in Hauptsmoor, near Bamberg. Smaller spars are also required which are of dimensions within the powers of most forests to supply.

FIG. 39.



Transverse section of a ship. (After Boppe.)

5. *Supply of Timber for Shipbuilding.*

The supply of oak-timber from German forests is only small, but they would be in a better position to yield masts and spars, if the Scotch pine forests of North Germany were specially managed to produce timber of large dimensions.

The system of coppice-with-standards is better adapted for the supply of oak timber for shipbuilding than the even-aged systems, and thus France, where this system is very prevalent, produces large quantities of suitable oakwood. Most of the timbers used in shipbuilding are compass-timbers, which are much more abundant in uneven-aged wood, and even in hedgerow trees, than in even-aged high-forest. The wood of standards in coppice is also harder, and of better quality for the purpose, growing as they do, isolated or in groups, with plenty of room both for their roots and crowns.

As regards mastwood the opposite conditions prevail, slow, uniform, and prolonged growth is required, and the trees must be grown close until they have nearly attained their full height, in a uniformly moist soil, a situation sheltered from storms, and a cold climate. Only individual trees in such woods will attain sufficient dimensions for the largest masts, and on them great care and attention must be bestowed.

Section VII.—Joiner's and Cabinet-maker's Work.

Joiners and cabinet-makers use large quantities of wood, which is usually the only material they employ. These industries have become highly specialised, and there are all grades of artisans employed—the joiner, the cabinet-maker, the wood-carver, model-maker, and tool-maker.

1. *Joiner's Work.*

The joiner constructs the inner fittings and finishing of houses, such as the floors, doors, window-cases, wainscoting, staircases, &c. The material he uses is chiefly sawn timber, planks, boards and scantling. He does not usually work with roughly sawn material, but with planed scantlings, &c., which are sold by the wood-merchants ready for use, and are often already cut into the requisite mouldings. Thus much labour is spared which would cost more if executed by a joiner than when made by special machinery. Hardly any wood in the round, or roughly sawn wood, is used by the joiner.

The wood used is chiefly coniferous, and broad-leaved wood to a less degree. Boards, planks, and upright pieces are chiefly of spruce, and after this, of silver-fir, pines or larch. Owing to its white colour spruce is preferred for flooring. Silver-fir turns grey and splinters more readily than spruce. Pines and larch are darker coloured but more durable than spruce. For wainscoting, Cembran pine and larch yield excellent wood. The joiner always prefers fine-ringed coniferous wood, free from knots, to coarser material, except in cheaply run-up buildings. Amongst broad-leaved woods oakwood is preferred, and is largely used for parquetry floors, for which the blocks are specially prepared by machinery. It is also used in short, flat, planed pieces, and beechwood is employed in the same manner. Oakwood is less frequently used for friezes, door- and wall-panels. Oak panelling made of wood showing the silver grain is used in dining-halls, staircases, churches and other public edifices.

Oak is also used for staircases, and so is beechwood, and ash is often turned for banisters.

Fine mosaic parquetry floors are made of woods of different colours, such as oak, walnut, birch, teak, &c., and cut in different ways as regards the grain. Some of the woods used are coloured by strong acids, others preserve their natural tints.

2. *Cabinet-making.*

Furniture is now-a-days made more in factories than by individual makers. It makes a greater demand on the quality and variety of the wood used than joiners' work, and equals it in the quantity of wood used.

Sawn timber is used in the form of planks and scantling and round wood of all dimensions. Veneer of finely marked wood is also frequently used to face coarser material, and its use is justified by the fact that these thin strips of wood do not crack, as is always more or less the case with solid woodwork.

Only the more valuable hardwoods are used in the round by the cabinet-maker.

All kinds of wood are used, and for coarser furniture, kitchens, cupboards, school-benches, frames, chests, cheap coffins, &c., coniferous woods and soft broad-leaved woods are used. The inner part of other furniture is made of these woods and then veneer glued on to it, or they may be covered with upholstery. Oakwood is often used for the inner part of the better kind of veneered furniture.

Solid furniture is made of broad-leaved species, such as oak, walnut, cherry, birch, maple, ash, elm, &c. There is, however, a limit to the construction of solid wood furniture owing to its weight. Beechwood is largely used wherever friction and wear and tear will be considerable, as in work-tables, chairs, wedges, &c. It is also often used stained in various tints to imitate more valuable woods.

The cabinet-maker selects his material for its fine colour, good texture, freedom from knots, ease in working, capability of being polished, and for being little liable to warp or crack. Finely marked and wavy woods are highly esteemed.

In order to reduce warping and shrinkage as much as possible, the cabinet-maker only uses thoroughly seasoned wood; he does not care for the most durable wood, but prefers wood which is easily worked, with, or against, the grain. He therefore means quite a different kind of oakwood from that esteemed by the ship-builder when he speaks of good oakwood, and prefers that of the sessile to the pedunculate oak. The best cabinet-maker's oakwood comes from the Spessart, the Pfalz, the Silesian mountains, from French forests managed under the even-aged high forest system, and generally from mountain districts with a slow rate of growth; on account of its lower density it is less liable to shrinkage. Slavonian oak and that from coppice-with-standards is much less prized.

Beechwood would be much more highly prized for furniture, on account of its dense uniform texture, were it more frequently obtainable from middling sized trees in quarter-balks from which the core of the tree has been excluded. Such wood is excellent material for working up, and is now being extensively used for bent-wood* furniture.

Thoroughly sound beech stem-wood free from knots is used for bent-wood furniture, and young wood is preferred to old. Even large pieces may now be easily bent, and the bending avoids sharp corners, dovetailing and glueing, the pieces being merely bent and screwed together. The wood is felled in summer and sawn into rectangular pieces 6–10 feet long and 1¼–2 inches in diameter, which give a waste of 60–70 per cent.

Beech-veneers are also glued together and made into the seats of chairs. These are now being used in increasing numbers.

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* See an excellent article by Exner on bending wood, in the Centralblatt für das gesamte Forstwesen. 1876.

Amongst softwoods of broad-leaved species, poplar-wood is chiefly used, and that of the black poplar is preferred, the wood of the white poplar being very subject to cup-shake. These woods are of very uniform texture, and the spring-wood does not shrink so much as in other woods, causing the summer-wood to project beyond it and giving the veneer, which is glued outside the piece of furniture, a wavy surface.

3. *Artistic and Fancy Ware.*

The manufacture of artistic and fancy ware forms a branch of cabinet-making, and is used in the finer pieces of furniture, picture-frames, clock-cases, &c.; according to the present fashion (old German, Italian, Renaissance, Rococo styles, &c.) it is more or less accompanied by artistic carving, inlaying with metals, mosaic work, &c.

Walnut, oak, fruit-trees, maples, birch and coniferous wood are used, partly solid and partly veneered.

Many exotic woods are used, especially mahogany and foreign walnut, maple and ash-burrs; also rosewood, satinwood, olive, cedar and cypress wood, teak and pitch pine.

Wooden frames for mirrors and pictures, which are largely made in Saxon and Bavarian factories and also by individual handwork, are made chiefly of coniferous wood, but also of oak and ash.

4. *Model-making.*

All models used for cast-metal works, of machines, implements, &c. are chiefly made of coniferous planks and scantling of the best quality and also of lime, maple, alder, ash, pear and beechwood. The model-maker is a real artist in his line.

5. *Wood for Tools and Implements.*

Plane-boxes, turning-lathes, presses, joiners-benches, mangles, handles of tools, &c., are chiefly made of beech, hornbeam, oak and ash. The framework of agricultural implements also uses up much coniferous wood, as well as the above species.

6. *Miscellaneous Goods.*

Many other industries may be added, which are also branches of cabinet-making; such as the manufacture of billiard-cues, sword-sheaths, and articles used in dairies and cheesemaking establishments.

SECTION VIII.—MISCELLANEOUS USES OF WOOD.

A very large quantity of wood is consumed in making packing-cases, for which coniferous wood of middling or inferior quality, and side-pieces and other waste timber are used, especially when the cases are fastened together by bands of zinc or iron. Casks used for packing are also made of inferior coniferous wood. Better and more durable classes of packing-cases are however coming more and more into use, beech being largely employed.

For small boxes used for packing soap and other small articles, wood of conifers, beech, poplar, aspen and lime are used, cut like veneers with special saws, or even a whole round block of wood is revolved against a sharp fixed blade, and converted into a sheet of wood for this purpose.

In France, light wood such as aspen is thus used to reduce as much as possible the gross weight of the goods. Wood-pulp and tin are also frequently used instead of wood, as the material for packing-cases.

German cigar-boxes are usually made of alder-wood, and the pieces without bark should be 9 inches to 1 foot in diameter and free from knots; they are sawn into planks, and the latter reduced to thin boards by the circular saw.

The wood of the West Indian cedar (*Cedrela odorata*, L.) allied to mahogany, is largely used for foreign cigar-boxes. Attempts to use other woods for the purpose, and especially stained beechwood, have failed owing to the warping of the wood. Cigars are pressed into a good shape in presses made of beech and hornbeam-wood.

A very large quantity of wood is used annually in the numerous pianoforte-factories, which in Germany alone turn out about 75,000 pianos annually. In piano-making all kinds of sawn wood (oak, beech, walnut, maple, lime and poplar, &c.)

are used, but the wood for sounding-boards is of a special kind. For this only coniferous wood is used, chiefly spruce, more rarely silver-fir.

The simple anatomical construction of sprucewood and the absence of vessels, the extremely fine evenly distributed medullary rays, the straight and long-fibred nature of the wood, and above all its uniform structure, render it most suitable of all woods for reverberating pure tones. Such wood must have narrow and uniform annual zones, must have no knots, contain little resin, be straight-fibred and of low specific gravity, 0·40 to 0·45. The best wood for musical instruments should have zones between 1·5 and 2 mm., and the summer-wood $\frac{1}{4}$ to $\frac{1}{5}$ of the zone.

Trees producing such wood grow in mountain-regions at altitudes between 2,500 and 4,500 feet above sea-level, on cool and not too fertile localities. They are generally grown in selection forests, where the trees get little room for development, until they are middle-aged, but more room as old trees.

Certain forest districts in Bavaria, Bohemia and the French Jura, are renowned for the production of this wood, also Galicia and North America. The trees are sawn into quarters, and then along the radius, into planks $\frac{3}{4}$ inch thick; they are then seasoned, planed, and sorted according to their tones.

Recently, attempts have been made to produce such wood artificially by glueing together thin veneers of wood by means of turpentine, shellac, gum, &c., and pressing it into planks.

Straight-grained beechwood in planks $1\frac{1}{2}$ inches thick is largely used for pianos, being cut along the radius, which prevents its warping as much as ordinary beechwood.

Many foreign woods are used for piano-cases—ebony, mahogany, American walnut, sycamore, &c., and Florida-cedar for the hammers. Woods similar to those in use for pianos are also employed in organ-building.

Venetian blinds and shutters use up much light wood, especially spruce, and wood of similar quality to that used for sounding-boards is used for the better sorts of blinds, much of it coming from Bavaria.

SECTION IX.—WOOD USED BY THE WHEELWRIGHT.

The wheelwright, besides carts, also makes a number of articles used in agricultural work, and comes in this respect next to the blacksmith as an indispensable village artisan ; he usually obtains his wood directly from the forest.

Wheelwrights' wood should be even-grained, long-fibred, tough and dense, and free from knots and all other defects and patches of decay.

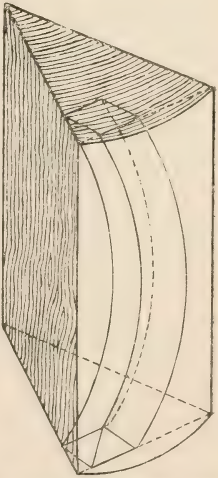
The chief industry of the wheelwright is the construction of carts and waggons, the principal parts of which are the wheels, axles and shafts.

The wheels consist of the nave, spokes, felloes and tires.

The **nave** or **hub** is generally made of oak, elm or ash, and in the case of carriages, of walnut, or, more recently, of plane-wood. The wood should be hard and dense to prevent the loosening of the spokes, which are morticed into the nave. [It is said that wych-elm-wood is tougher, finer-grained, and more easily bent than common elm-wood, both woods are largely used for naves and felloes.—TR.]

The **felloes**, which are afterwards morticed together in a circle, are generally made of split wood of elm, beech, birch, ash or robinia, elm being best for the purpose. The wood should, if possible, be naturally curved, and as the pieces are only about 2 feet long, there is generally little difficulty in getting nearly the suitable curve, the wood being then cut into shape with a band-saw.

FIG. 40.



Mode of cutting out felloes. (After Fernandez.*)

There is a large export of felloes from forests, and in Germany they are usually sawn out of split pieces, with their flat sides parallel to the annual rings (fig. 40), which enables them best to support the pressure of the spokes

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[*] Fernandez, Utilization of Forests, p. 54.

without warping. Where felloes are sawn out of ordinary planks 3 to 6 inches thick, they are much weaker than those made as above.

A bent rim is sometimes used for the wheels of light carriages, being made of one piece of steamed split-wood; larch, ash, oak, beech, birch, or hickory are employed.

Spokes are made of cloven oak- and ash-wood, also of robinia, American oakwood or hickory. Wood thoroughly tough and strong, and not likely to shrink much in dry, hot weather, should be used.

[Spokes vary greatly in size, the smallest being 2-2½ feet long × 2 to 2½ inches × 1 to 1½ inches and tapering down to about ½ inch at the smaller end; these are used for omnibuses and coaches. Cart-wheel spokes are heavier, but of about the same length. Large spokes 5 inches × 3 inches at the thicker end are frequently made.—Tr.]

The principal piece of the body of a timber-cart is the **pole**, which is made of oak, birch, or ash. The axles of the wheels are usually made of steel, or of strong oak or ash-wood, with steel ends on which the wheels revolve. **Carriage-poles** are preferred of birch, but are also made of ash and oak; and for **shafts**, ash is preferred to oak, the latter, when strong, being usually too heavy, whilst ash bends and yields better without breaking. The best shafts are of hickory or lancewood (*vide* p. 174). The size for shafts is 8 to 10 feet by 2½ to 4 inches square.

The **framework of carts and carriages** must be made of well-seasoned wood, beech, ash and oak being used, the panels of carriages being of lime or poplar.

Ploughs and harrows are made of heavy wood wherever iron is not used in their construction, and crooked pieces of oak, ash and elm-wood are used. Teeth of harrows are made of hornbeam-wood if not of iron.

For **sledges**, oak, birch, elm, ash and beech are generally used, and their horns are made of the best beech, maple, or birch-wood. **Wheelbarrows** also require carved wood.

Ladders consist of two uprights and the rungs, the former made of coniferous wood, generally of a pole sawn in two, and the latter of cloven wood of oak, ash or robinia. **Mangers** have a similar construction to ladders, and are made of beech, birch or oak.

The manufacture of the **handles of tools** requires large quantities of wood, as axe- and hatchet-handles, and handles of hammers, spades, scythes, hoes, thrashing flails, &c.

Split pieces of young beech saplings are chiefly used for axe-handles, as well as of hornbeam, oak, juniper, ash, and the service-tree. Beech or birch handles for scythes; for spades and hoes, ash, elm, robinia, oak and birch are used. Wooden **hay-forks** are made out of forked birch, ash or aspen; wooden brakes for wheels, of beech or hornbeam.

In making all these articles the wheelwright uses logs and scantling of different dimensions, above all, logs of 3 to 8 inches in diameter of oak, ash, elm and birch, but all kinds of wood are used, and chiefly cloven wood, from which the core and the sapwood have been removed, as such material is less liable to warp or crack. Curved and bent wood is often of special value to the wheelwright, although such pieces are frequently made artificially.

Elmwood affords excellent material for the wheelwright, sometimes that of the common elm and sometimes that of the wych-elm being preferred, but it is very difficult to work, and costs the artificer more labour and trouble than he often cares to bestow. Near the sea-coast much exotic wood, ready cut to size, is used by wheelwrights, especially American hickory (*Caria*) and oak (chiefly *Quercus virens*).

Butchers' blocks use up much beech- and oak-wood, though elmwood is best for the purpose, if it can be obtained of suitable dimensions. Pieces of large diameter, and thoroughly sound, are required.

The manufacture of **railway-carriages and -trucks** consumes enormous quantities of wood of high quality. The horizontal beams underlying all passenger-carriages as well as goods-trucks are made of squared oak timber. They lie between the iron girders supporting the carriage, and rest directly on the axles. Broad-ringed ashwood is preferred for the uprights, which are dove-tailed into the horizontal beams and pieces which unite with them to form the framework of the carriage, but oakwood is sometimes used, and also more recently the wood of *Ailanthus glandulosa*, Desf. The flatly-curved roof-supports are made of bent elm, ash, or Scotch pinewood. All panels and the interior work are made of light woods, coniferous, poplar-wood, &c., also of sheet-iron, and, more recently, in England, of pressed oakum made out of old ship-cables.

In the frequently very luxurious passenger-carriages and sleeping-cars, valuable ornamental veneers are used in the internal fittings, or exotic woods, such as teak, American walnut, fine ash, maple or mahogany, are used in a solid form.

Even the iron goods-trucks require about 36 cubic feet of ash- and oak-wood in the construction of each truck, and there are 200,000 goods-trucks on the German railway-lines alone.

SECTION X.—COOPERS' WORK.

The cooper makes all kinds of open or closed wooden vessels to contain liquids and dry articles. A distinction may be made between casks intended to hold spirituous liquors, to hold other fluids, and for dry goods, such as butter, sugar, herrings, &c. Nowadays casks are chiefly made in factories.

1. *Casks for Spirituous Liquors.*

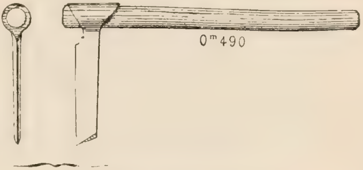
The most important use for coopers' timber, and which employs large quantities of the best kinds of wood, is the manufacture of casks for spirituous liquors, such as wine, beer or cider, &c. A good cask should be as durable and strong as possible, in order to withstand the inevitable shocks and rough treatment to which it will be subjected during transport. It must also possess the property of retaining its liquid contents, so that the latter does not escape in drops or vapour through the wood-pores. Hardly any wood but oakwood will fulfil all these conditions, and especially pedunculate oakwood from favourable localities, which is superior to northern sessile oak for staves. The latter should be used in thicker staves to compensate for its inferior density.

In Italy robinia-wood has a good repute for staves, whilst sweet chestnut, Turkey and evergreen oaks, are less valuable. Attempts have been made to utilize beechwood for wine and beer-barrels, but without success. For spirit-casks, ash, robinia, and mountain ash-wood are also used.

Casks are composed of side-staves, head-pieces and hoops.

The side-staves should be broadest at their centres and taper off towards their ends, in order to allow for the bulging of the casks; they should, however, be somewhat thick again at their ends, as a notch has to be cut there to admit the head-pieces. The two broadest staves are that on which the cask rests, and the opposite one in which the bung is inserted. The best wood is used for these two staves. From three to five head-pieces are used at either end of a cask, being dovetailed together. The tops and bottoms of small casks are flat, but in larger ones they are somewhat curved inwards, in order better to withstand the pressure of the liquid inside.

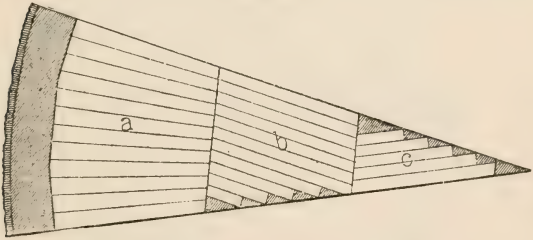
FIG. 41.



The divider. (After Boppe.)

Wood for staves is usually cloven in the forest by special artificers, and straight-grained, light and sound wood, free from knots and other defects, is employed. It must be strong, and yet pliable and easily cloven; it is split with a special instrument, termed a divider (fig. 41), in the radial direction, so that the silver-grain is visible on the broad surface of the staves, as the wood is least permeable in the direction at right angles to this. Whether, or not, wine leaks out of casks appears to depend on the size of the pores, for it finds its way into the anatomical wood-vessels and oozes out at the ends of the staves.

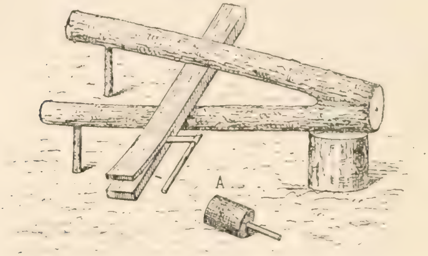
FIG. 42.



Method of splitting wood for cask staves. (After Boppe.)

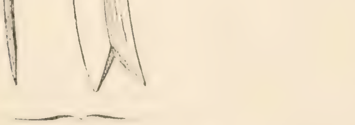
In the preparation of staves, an oak stem is first cut into suitable lengths, which are then split in halves by means of a wedge. Each half-log is then further split (fig. 42) into three or four sectors, and after the core and sapwood have been removed these are split tangentially into pieces as wide as the staves by means of the divider driven by a wooden mallet. These pieces are then fitted into a stave-maker's bench composed of the fork of a tree (fig. 43), resting on three stakes driven into the ground, and are then split radially into staves, and trimmed smooth by means of the shave (fig. 44).

Fig. 43.



Stave-maker's bench with divider and mallet. (After Boppe.)

Fig. 44.



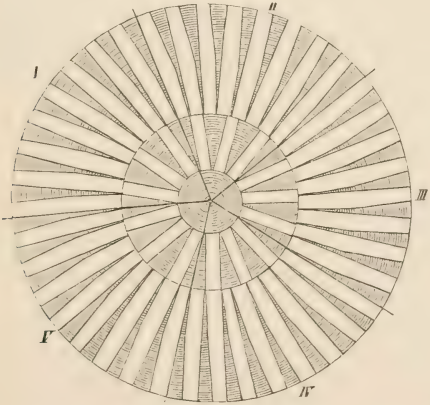
The Shave.

In Germany, the staves are also partly dressed into a curved shape with the adze, but in France they are bent into shape. The dimensions of the staves vary considerably, according to the demands of the trade. The broadest pieces are required for heading vats, and can only be taken from large trees. The Polish staves, which are exported from North Germany to England, France, Spain, &c., are classified as follows:—

Class.	Length.	Remarks.
Pipe-staves	5 ft. 2 in. to 5 ft. 4 in.	—
Hogshead-staves	4 ft. 2 in. to 4 ft. 4 in.	3 pieces equivalent to two pipe-staves.
Barrel-staves	3 ft. 2 in. to 3 ft. 4 in.	2 pieces equivalent to one pipe-stave.
Head-pieces	2 ft. 2 in. to 2 ft. 4 in.	4 pieces equivalent to one pipe-stave.

There is a very large demand for staves for the wine and beer trades, which are exported from the Baltic, Fiume and Trieste, and from North America. The best staves come from Croatia, Slavonia, Hungary, and Bosnia, which countries produced about 26,000,000 staves in the two years 1891 and 1892. The Bosnian staves are more easily worked, and are therefore preferred to those from Slavonia. Oakwood from those countries is sound and heavy, and the markets for it are Fiume and Trieste for France and England, and Vienna for Germany, the best staves going to France. These are made as shown in fig. 45, from the best oak trees measuring (without sapwood) 22 inches in diameter.

FIG. 45.



In the trade, the staves are sold in lots each sufficient to make up into a cask of different dimensions, or for France, in hundreds.

The import of staves from America is steadily increasing at Bordeaux, Liverpool, Hamburg, &c., and is reducing the price of European wood.

The waste of wood in making staves varies from 30 to 50 per cent.

After rough staves have left the forest they require further trimming and shaping by the hand of the cooper, and must be allowed to season in piles in the open for several years before they are fit to make serviceable casks. If, however, they are steeped in water when quite green and then carefully dried, they may be made into casks two years after leaving the forest.

Machines are used in England for making casks, and the latter are much more regular and of better appearance than those made by hand: it is only questionable whether casks made of sawn staves are as durable as those made of split ones. In other countries machines are no longer used for cask-making, as they do not exclude subsequent manual labour in finishing the casks. It is stated that in America beer-barrels can now be made of papier-mâché, which material has for some time been used for oil-barrels.

2. *Slack Barrels.*

Slack Barrels are used for non-spirituous liquids, &c., such as those used for the transport of herrings and other sea-fish, for living animals, for oil, bathing- and water-tubs, malting-vats, milk-pails and a number of other articles.

Herring-barrels were formerly made of inferior oakwood, but more recently of beech, birch, alder, red pine and aspen-wood. Large malting-vats, and other vats used in brewing, are made of oakwood. Oil and petroleum casks are made chiefly of beechwood, but also of oak and chestnut-wood. Other slack barrels are made almost exclusively of coniferous wood, only smaller drinking-vessels being made of maple, pear and cherry-wood, or in preference, of juniper or Cembran pinewood.

In splitting wood for staves for slack barrels similar methods are followed as already described; the staves are, however, commonly split along the annual rings, or made of good sawn material. Freedom from knots, and even fibre, are also here the first conditions of suitability.

3. *Barrels for Dry Goods.*

Dry Goods' Barrels are employed for storing and transport of all kinds of wares, such as salt, colours, cement, gypsum, sugar, currants, figs, butter, lard, chemical preparations, &c., and are usually made out of coniferous wood.

Staves for these barrels are seldom split, but are usually sawn pieces, half an inch thick, 2—6 inches broad and varying in length; poles, 4—4½ inches in diameter at height of chest, may be thus utilized.

Larger wood, chiefly of beech, is used in Hungary and North Germany for currant-, flour- and butter-barrels.

Barrels for dry goods are chiefly made in factories, and there are large factories at Münden, Hannover, &c., for making margarine barrels. Smaller barrels are made of papier-mâché with wooden headings. [The fig. on p. 174 shows a method employed for splitting spruce-staves in the Jura.—Tr.]

4. *Barrel-Hoops.*

Hoops for barrels are now-a-days increasingly made of iron, but a large quantity of wooden hooping is still used. Coppice poles of oaks, chestnuts, birch and hazel are used, and of willows for the smaller casks. They should be felled before the leaves are out. The coppice-shoots are cut with bill-hooks, trimmed of all twigs and knots, and then split in halves. When green they can be easily bent to the requisite shape, but if dry must first be soaked in water. In the case of slack barrels the hoops are chiefly made of pieces of the stem of ash, spruce, or willow trees, 2 inches broad, and ⅓rd to ⅔rds of an inch thick. They are cut smooth with a knife, plunged into boiling water, and bent over a round piece of wood.

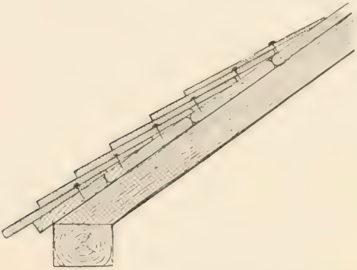
SECTION XI.—SUNDRY USES OF SPLIT WOOD.

Some other articles besides casks and barrels are made of split wood, or of wood treated in a somewhat similar manner.

1. *Shingles for Roofing or to cover Walls.*

Shingles are either used for roofs, or to cover masonry or cement walls, which do not otherwise sufficiently exclude atmospheric moisture. The most durable shingles are made of oak- or larch-wood, but owing to the abundance of spruce and Scotch pine, wood of these species is chiefly used, and less frequently silver-fir wood; beech- and aspen-wood are also sometimes employed. The butts to be split must contain sound, light, and straight-grained wood without knots, and therefore the lower part of stems is chiefly employed. Wood of inferior grain, and less fissile may, however, be split by means of machines.

FIG. 46.



Shingles are prepared of very different sizes, according to the manner in which they are to be used. Roofs are usually covered with shingles three deep, *i. e.*, only a third part of each shingle being exposed (fig. 46), and such roofs are very durable and watertight. Shingles used in this way are 16—24 inches long, 3—10 inches broad, and from 2 inches down to half an inch thick. In many countries they are so thin at one end as to be semi-transparent, especially in the case of larch-shingles. Another kind of roofing (Legdächer) is frequently employed in Alpine districts, the shingles being 30—40 inches long, and 8—12 inches broad. They overlap one another, and are fastened-down by nailing split laths over them. In the case of tiled roofs, thin laths, 12—14 inches long and 2—3 inches broad, are placed wherever one tile is superposed over another.

Shingles are split radially from the butts, and the sectors thus obtained are continually split until pieces of the right dimensions have been secured; they are then made smooth. As the central portion of the butts cannot be used for shingles, there is a loss of 35 to 40 per cent. of wood in making them, and even more. Machines have been invented for making shingles, that by Gangloff* being the best known; a man and boy can thus make 700 shingles in a day, and wood of inferior quality may thus be utilized. Shingles stained black or red, the better to resist the weather, are prepared in Sweden. Fire-proof shingles are also employed.

[In the Western Himalayas, deodar, and other conifers are used for shingles, the former wood being extremely durable.—Tr.]

2. *Wood for Oars and Rudders.*

Large quantities of wood are used for making rudders and oars. Ashwood is best, but beechwood is also used. The pieces used for the purpose are 6—15 feet long, 4—5 inches broad at the flat end, and 2½—3 inches square at the other end.

Large spars used to stretch the large nets used by English fishing-boats may be also included here. The wood used is in round or split pieces of slender ash-stems 24—30 feet long, and 7—8 inches in diameter at the top. Oars for light river boats are made of split sprucewood.

3. *Broad split Pieces.*

Thin pieces of wood are used for making boxes, sheaths for swords or knives, by the bookbinder, shoemaker, &c., and are chiefly of coniferous wood (spruce), but wood of beech, aspen, and birch is also used. They are split out of butts, or straight-fibred split billets.

Wood-Tapestry of the thickness of ordinary paper is used for coating the walls of rooms, up to 3 feet broad and 60—100 feet long, and is prepared from the wood of all species of trees. This is obtained by supporting the butt on a special kind of turning-lathe, and revolving it against a blade which is constantly pressed further forwards as it peels off the periphery of the butt. The same machine may be used for making veneer.

Straight-grained sprucewood is also split and used for making **plaited wooden baskets** which are exported in large numbers from the Erzgebirge. Aspen- and lime-wood is also similarly used. In order to prepare the wood for this purpose, it is first thoroughly soaked in water and cut into bars, which are split into thin pieces along each of the annual rings. These pieces are extremely flexible.

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* Forst. u. Jagdzeitung, 1872, p. 312.

Sprucewood is also used for **sieve-frames** and **cheese-moulds**, the wood for which is separated from ordinary split billets with the cooper's divider, and afterwards planed with the same instrument. These pieces are made in different dimensions, their length being measured in hands (4 inches): thus there are pieces of 4, 6, 8, &c., up to 24 hands, the breadth varying with the length between 2½ and 8 inches. Wood must be used green for this purpose, the preparation of the pieces and subsequent bending being thus facilitated.

The pieces are then bent on simple frames, and fastened in bundles of 10 to 15 pieces for sale. Wooden rings are also made wider than the frames, but only ⅓rd of their height. The bottoms of the sieves are fixed between the frame and the ring.

The sides of **measures for fruit or dry goods**, and of **drums**, and other round articles, are split radially from billets of beech- or oak-wood, from which all defective heartwood and the younger zones of sapwood have been excluded. They are split with the divider, worked smooth on the cooper's bench, steamed and bent around frames. They are then sorted, and sold in assortments like sieve-frames.

The **band-box maker** chiefly uses spruce and silver-fir wood, less frequently larch, sycamore, and sallow wood. Butts of straight-grained wood are cut into the proper lengths, and split into from 4 to 6 billets, and after these are thoroughly dried they are gradually split by successive bisection into pieces of the required dimensions.

The pieces are then carefully planed, softened in boiling water, fastened over frames, and when thoroughly dried are fastened together by wooden bands. The bottoms and lids for each box are made in a similar manner.

Oblong **lucifer match-boxes** are chiefly made at Jönköping of aspen-wood by means of machines, which cut out a piece large enough for a box, and press dents into the wood wherever a side has to be bent inwards. In the absence of aspen-wood, wood of lime or poplar is used in Germany for these boxes.

4. *Wood-Wool.*

Wood-Wool may be mentioned here, which is made from even-grained wood, chiefly coniferous, though any species of wood may be used, in round pieces one to two feet long, and is used instead of hay, seaweed, &c., as packing-material; for stuffing chairs, and other furniture; as stable litter; for preserving ice, and in surgery, &c. It is also made into ropes.

Villeroy, in Schranberg, compresses very fine wood-wool under high pressure into a sort of papier-mâché which is very durable, and is used for rules, carvings, ornaments, &c.

The machine for making wood-wool consists of an implement working in a groove, and composed of a number of small vertical knives which cut the wood in the direction of its fibres, and a plane moving vertically which cuts-off the separate strands of wood. Such a machine can turn-out three cwt. of moderately fine wool in a day.

5. *Slender Pieces of Wood.*

Slender pieces of wood are used for making handles for paint-brushes and pens, flower-sticks, &c., also wooden thread for making lucifer-matches and other articles. Fissile straight-grained sprucewood is used for these purposes. The pieces used for paint-brush and pen handles and flower-sticks are in section either round, semi-circular, oval, or quadrangular, and of various lengths up to 5 feet. They are prepared from wood in the rough by machines. Grasenau, in Bavaria, is one of the chief seats of this industry.

Wooden thread is now prepared on a large scale, either in round pieces of sprucewood 8 to 30 feet long, or in short pieces, used for lucifer-matches in Germany and Sweden.

The round pieces, usually $\frac{1}{12}$th of an inch (2 mm.) thick, are made only from the finest grained sprucewood, and the refuse of musical instrument wood may be thus utilized. They used to be made by manual labour with Romer's plane, which, instead of an ordinary cutting blade, has a blade with a number of funnel-shaped grooves, each of which cuts-out a cylindrical thread. After a layer of thread had been planed away, the wood was planed smooth by means of an ordinary plane, and a fresh layer of threads then removed.

At present manual labour has been replaced by machinery constructed on the principle of Romer's plane. The threads are then woven with stout twine into blinds, floor-coverings, table-covers, &c., and are specially useful for **chicks** in tropical countries, which, hanging before doors and windows, allow sufficient ventilation, while excluding the glare of sunlight and insects.

The short pieces used for lucifer-matches are made from the most various woods, especially those of spruce, Scotch pine, silver-fir and aspen. They are prepared in factories according to three different methods. The oldest method, and that still most usual in Germany, is by means of Romer's plane, which in this case is perforated by twenty-five to thirty little cutting tubes, one above the other, through which the wood is forced by the workmen. The serviceable pieces are then separated from the unserviceable pieces by machinery, and placed five hundred together in boxes, which are fastened by rings into large bundles containing several thousand pieces; a workman can prepare 200,000 pieces in a day.

Another method is employed in Sweden, only aspen-wood being thus used. The round piece of rough wood, 1½ feet long, is softened in water and fixed between the points of a lathe, and the wood is then turned against a blade which peels-off from it a long piece 1½ feet broad, of the thickness of a match. This is then cut and split by machines into separate pieces, each the size of a match. The Jönköping factories alone used up, in 1883, 280,000 cubic feet of Russian aspen-wood for this purpose.

Pieces with a quadrilateral section are prepared after a third method, machines similar to those in use for wood-wool being employed.

The manufacture of lucifer-matches is steadily consuming more and more wood, and there are factories which for matches and match-boxes consume 200,000 to 300,000 stacked cubic feet of wood annually. Thirty-five stacked cubic feet of wood will yield 2,000,000 lucifer-matches 2 inches long, weighing 3¾ cwt. The yearly requirements of Europe in this respect are estimated at more than 3,500,000 cubic feet of wood.

6. *Trenails.*

Trenails are wooden pegs of different sizes, the largest being used in shipbuilding and smaller sizes by the cabinet-maker and joiner, for fastening pieces of wood together; the smallest kinds are used by shoemakers.

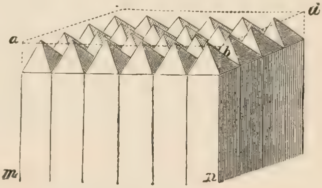
Ships' trenails are in lengths of 4, 8, 16, 28 inches, 1½ to 3 inches thick, and are made of robinia, ash, and mulberry-wood. Thirty-five stacked cubic feet yield on the average 200 trenails.

Trenails used by joiners and cabinet-makers are made of the wood of oak, fruit-trees, beech, and even of coniferous wood, besides that of robinia and ash. Shoemakers' pegs are made of birch, hornbeam and sycamore.

The larger kinds of trenails are made by machinery as follows:—A round piece of wood is cut to the length of the nails, and then placed on a sliding frame, which forces it against the cutting-blade. It is thus split in one direction, and then turned through an angle of 90° and split again. The split pieces are then pointed conically by machines.

Shoemakers' pegs are similarly made, only here, as in fig. 47, the points are made by means of planes running first along *a b*, and then along *a c*. The pieces are then split vertically (*a m*). There are factories in Silesia where annually 35,000 cubic feet of wood are made into shoemakers' pegs.

Fig 47.



Large numbers of wooden toothpicks are made at Weissenfels and other places, of soft, white wood, chiefly willow.

7. *Lead-Pencils.*

The best wood for lead-pencils is the so-called cedar (*Juniperus virginiana*, L., and *J. bermudiana*, L.), but inferior pencils are made of the wood of lime, spruce, Cembran pine and poplar. The wood is partly split and partly planed into shape.

8. *Wood for String Musical Instruments.*

Split wood is used for making violins, violoncellos and other string-instruments. As steamed woods more or less curved and pressed into shape are required, only split wood, and not sawn wood, can stand the strain. The fronts and backs of the instruments are made of spruce and silver-fir wood, and their sides of sycamore. As regards fine zones and uniform structure, wood of even superior quality to that used for pianofortes is required. The zones in the wood for violins should not exceed 1 to 2 mm. ($\frac{1}{25}$ to $\frac{1}{12}$ inch); for double-basses and violoncellos it may be coarser-textured, 2 to 4 mm. ($\frac{1}{12}$ to $\frac{1}{6}$ inch).

The higher the key, the finer the woody zones should be. This valuable wood is steadily becoming scarce. Up to the present it has been obtained from selection forests, in which the suitable trees are found disseminated. It is rare that an entire stem can be used for making musical instruments, only certain portions of it being suitable. These pieces are exported in split sector-shaped pieces, from which the core has been removed, in lengths of 16 to 30 inches for violins, or of 40 to 60 inches for the larger string instruments. Grasenau (in the Bavarian Forest), Mittenwald (in the Bavarian Alps), and Markneukirschen (in Saxony) are the best known markets for these goods.

SECTION XII.—GLAZIER'S WOOD.

Glaziers formerly used chiefly oakwood for window-frames; less frequently, wood of sweet chestnut, elm, larch and Scotch pine. More recently, in large towns, the better kinds of Scotch pine-wood [or teak.—TR.] have replaced oak for this purpose. The glazier requires oakwood of similar quality to that used by the cooper; it is generally sawn, with a nearly square section, or is taken from the refuse wood after splitting staves, or is split from billets. Sawn oak planks are used for the larger windows. The advantage of split wood for this purpose is that it warps less than sawn wood. Coniferous window-frame wood comes into the market ready prepared by machinery. Iron is steadily replacing wood for window-frames, especially in windows of shops and other large buildings.

Section XIII.—Wood-Carving.

The wood-carver is represented by a whole class of artizans who use a number of chisel-like tools, especially in the finish of their products. The following classification of these wares is attempted :—

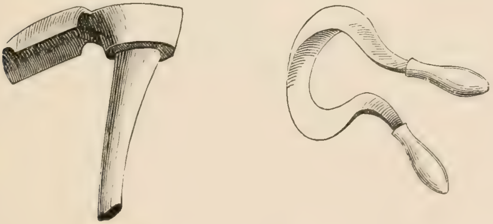
1. *Coarse Wood-Carving.*

All sorts of bowls, plates, platters, corn, meal, and bakers' shovels, kitchen-rollers, milliners' blocks, milk-ladles, wooden spoons, wooden shoes, shoemakers' lasts, saddle-trees, &c. Beechwood is chiefly used for these articles, and sycamore-wood for cooking apparatus; wood of birch, aspen, lime and poplar are also used, and boxwood for the finest Russian wares.

Short wooden butts are chiefly used, which for the larger bowls, platters, &c., should be 3 feet and more in diameter, and, on account of their size, are becoming scarce. For smaller articles, and especially **sabots**, or wooden shoes, the better sorts of timber are required. All the timber used should split easily, be perfectly sound and free from defects and knots.

As the finished articles must be, above all, safe from warping and sufficiently strong, the cuts should be along their lines of greatest extension. The butt is therefore split into from four to six sectors, from which the core and bark are removed and the shape roughly hewn-out with an adze. The further finish is given to the articles with special instruments, which are bent according to its shape, and of which figs. 48 and 49 represent general types.

Fig. 48.



The remarkable progress which has been made recently in wood-working machines favours the idea that handwork on rough wood-carving will become in time more and more replaced by machinery. The turning-lathe is already largely used for round articles, whilst machines* have now been invented by which almost any shape may be given to wooden articles. These machines work with a revolving steel blade, which cuts the piece of wood according to the model, much more rapidly and exactly than handwork can ever attain, and with much less waste of material.

Wooden shoes are made by hand, of the wood of beech, alder, birch, hornbeam, walnut or poplar, the split pieces being first roughly trimmed into shape by a short hatchet and then finished with various curved instruments. Trees 1½ feet to 2½ feet in diameter at height of chest are preferred for this purpose. In order to give the shoes a dark colour and preserve them from splitting whilst being gradually dried, they are smoked. The finer kinds are made of poplar or willow-wood and blackened. The Département of Lozère, in France, alone produces 600,000 pairs of wooden shoes yearly. [Wooden heels of women's boots are extensively made in Normandy.—Tr.]

Wooden soles for leather boots and wooden pattens and clogs are largely made in Saxony by machinery. Shoemakers' lasts are chiefly made of hornbeam-wood, and failing that of beech or sycamore ; there are large factories of these articles in Bohemia and Saxony, in which machinery is used.

Broomheads are made chiefly of beech and cherry-wood. They are chiefly made at Globenstein in the Erz mountains, at Esslingen, and at Todtenau in the Black Forest, where £25,000 to £30,000 worth of broomheads are made yearly.

Wood is mostly used green for rough wood-carving, as it is then easier to work.

2. *Gunstocks, Wind-Instruments, &c.*

For gun- and pistol-stocks wavy † wood of walnut, maple, birch, elm and sycamore is used, chiefly from the lower part of the stem and the roots. Beechwood is also used for inferior muskets. The various wind-instruments, clarionet, flute, fife, &c., are made from boxwood, and wood of ebony, birch, service-tree, maple, and grenadil; wooden pipes from **bruyère** (*Erica arborea*, L.), alder, maple, birch and sycamore. All the wood used must be first dried, and again from time to time laid aside to dry during the making of the instruments, or it would soon warp. Klingenthal and Markneukirchen in the Erz mountains are the chief places for the manufacture of flutes, &c. [Briar pipes from the S. of France.—Tr.]

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* Kopierfrais machine and Kopier lathe.

† Maserholz.

3. *Children's Toys.*

Enormous numbers of these pretty articles are made by dovetailing little cut pieces of wood, also by the turning-lathe and by carving. Sprucewood is chiefly used, between 60 to 70 per cent. of the whole, also wood of lime, oak, aspen, birch and alder. Regarding the importance of this trade, it is noted that at Olbernhau in the Erz mountains 1,000 to 1,500 tons, worth £35,000, are made yearly. The work is done by manual labour and by machinery; and there are factories where only one special toy is made (for instance, toy-guns).

Little animals which are afterwards painted to imitate nature are, in the Erz mountains, split-out from rings of sprucewood, which have been turned on a lathe, so that the animals are roughly formed along their radii.

This vast industry, of which Germany had for many years a monopoly for the whole world, has now taken root in other countries, under protective duties, and toys are now exported largely from America.

4. *Artistic Wood-carving.*

The art of wood-carving attained its highest perfection in the 14th and 15th centuries A.D., but after a long slumber has recently somewhat revived. Moderately hard, fine and homogeneous woods are most suitable for this purpose, in which neither the annual rings nor the medullary rays are too prominent.

Limewood is best, and then comes the wood of sycamore, horse-chestnut, walnut and fruit-trees. Oakwood is much used for carving, mountain and Cembran pinewood for inferior work. Besides carvings in which human figures and beasts are imitated, ornamental furniture is largely made, and frames for mirrors, clock-cases, &c.

Numerous smaller articles, such as ash-trays, salad-spoons and forks, paper-weights, napkin-rings, photograph-frames, &c., are produced in large numbers. There are now places, such as Oberammergau, in which wood-carving, fostered by schools of art, forms the chief occupation of the people.

[Fine wood-carving has long been a specialty in India, and very valuable art-furniture is now made in the Punjab and other provinces. —Tr.]

A special form of wood-carving consists in the large wooden type used for advertisements, notices, &c. Pear and apple-wood, sycamore and boxwood are chiefly used, and this industry has its chief seat in Switzerland.

[Wood-engravers use almost exclusively boxwood for their plates to illustrate books and newspapers, and this wood is constantly becoming rarer, selling at from £20 to £30 a ton in London. There is a considerable area of boxwood forest in the Himalayas, the protection of which is highly advisable.—Tr.]

Section XIV.—Turnery.

The turner employs hard, homogeneous wood capable of being polished, and besides using many exotic woods, such as box, ebony, &c., prefers the wood of beech, sycamore, hornbeam, service-tree, birch, aspen, yew, walnut and fruit-trees. Split pieces of wood are chiefly used, and the turner purchases round butts or split billets.

Although the demands the turner makes on the forest are only small, it is interesting to give an account of some of his wares. Large wooden screws for wine or oil-presses are chiefly made of the wood of pear, apple or hornbeam ; for mangles for pressing linen, of the same species, and also of sycamore, service-tree and beech. Turned legs and other pieces for ornamental furniture are chiefly of walnut-wood. Hat-moulds are made of lime or alder-wood ; skittles are made of hornbeam, pear and service-wood ; bowls, of lignum-vitæ ; shuttles, of boxwood; reels for thread, of birch and aspen-wood; spindles, chiefly of beechwood; pipe-stems, of apple, cherry, plum, maple, &c.; walking-sticks, of oak or ash coppice-shoots, white-thorn, vine-stock, dogwood, fruit-trees, and many exotic woods such as those of olive, greenheart, &c.; cask-taps, of pear, apple, yew, larch and Cembran pine; bungs are made of split oakwood and inferior sprucewood. Wherever these articles are made in factories, the demand on neighbouring forests may be considerable; as, for instance, for spindles, wooden buttons, bungs, handles for tools, &c.

SECTION XV.—PLAITED WOOD-WORK.

This section may be divided into **basket-work**, and **plaited wood-work** properly so called.

1. *Basket-Work.*

The basket-maker prepares wares of all shapes and dimensions, from coarse hampers, fish-traps, &c., to the finest kinds of baskets. The materials used are osiers, chiefly of *Salix viminalis, purpurea, rubra, amygdalina, triandra, Lambertiana, pruinosa,* &c., also shoots of birch and of climbing plants, and the finer roots of Scotch pine, mountain-pine or larch. The best osiers are thin yearling shoots, free from branches, about six to eight feet long, with white, soft wood; one or other kind of willow is preferred, according to locality, but *S. viminalis* and *amygdalina, purpurea* and *rubra* are the best esteemed.

For superior basket-work, the osiers are peeled, which is done immediately after they have been cut, when the sap is rising. The osiers may, however, be peeled, if they are plunged into water at a temperature of from 100 to 120° Fahr., without becoming impaired in colour or texture. After being peeled the willows should be thoroughly dried by exposure to the sun and air, or they will turn bluish and become brittle. They must be steeped in water when used, in order to recover their flexibility. For rough hampers and fish-traps the coarser osiers up to $\frac{1}{2}$ inch thick are used, unpeeled, but freshly cut.

Coarser baskets are made from unsplit osiers, the thin ends being cut-off, so that the thickness of the pieces used may be fairly uniform. Finer basket-work is made of split osiers.

In vine districts a large quantity of osiers are used as withes for fastening the vines to their supports. *S. viminalis* and *alba* are chiefly used.

2. *Wood-plaiting.*

Wood-plaiting is the most highly artificial employment of wooden threads, which are woven on a frame into various articles. The simplest of these are sieves, mats and carpets made of wooden threads at Klein-Cerma, in Bohemia. Silver-fir fibres are chiefly employed in strands 16 to 24 inches long, spun into threads and woven into carpets.

The finer kinds of goods are formed of woven material, which is afterwards bent over moulds into hats, purses, cigar-cases, table-covers, blinds, &c. Alt- and Neu-Ehrenberg in Northern Bohemia are the chief seats of this industry, and only aspen-wood is used, the wood being imported chiefly from Poland, and kept in pits under water till required.

The wood-fibres are prepared by the use of planes with numerous longitudinal groovings, and from them the material is woven on looms in pieces 2½ to 3 feet long and 2 feet broad. The threads are sometimes coloured.

Another way of making textile fibres from wood is to boil pieces of sprucewood, 8 or 9 inches long, with gypsum, as in cellulose-factories, so that the wood becomes resolved into its ultimate fibres. These fibres may then, like cotton or hemp, be spun into threads and twisted into ropes. In California this material is used on a large scale for various purposes.

SECTION XVI.—WOOD-PULP.

1. *For Paper-Manufacture.*

The conversion of wood into its component fibres prepares the way for paper-manufacture by means of wood. For some time past the increasing scarcity of rags has attracted the attention of manufacturers to substitutes from which paper can be made, and of these, wood has hitherto proved the cheapest. Means have been found to convert wood into a kind of pulp, which may be advantageously used to make paper. Wood-pulp is not only cheaper than pulp made from rags, but takes impressions better, and wears out type less. On the other hand, paper made of wood-pulp soon becomes brittle and turns yellow, so that there is a danger that it may be torn, after ten years or so, and it is therefore useless for important documents. Pure wood-paper can therefore be used only for pasteboard, packing-paper, and the coarser kinds of printing-paper. The better and finer kinds of paper require a certain admixture of rag-pulp or esparto grass, although wood-pulp has, to a large extent, taken the place of the latter.

At first, aspen and lime-wood were preferred for making paper pulp, but as the supply of these woods was quite insufficient for the demand, coniferous wood was tried, and spruce soon came into the first rank for the purpose. Besides the above woods, those of poplars, beech, and birch are also used. The assortments most in demand are poles and stems (converted into billets, as for firewood), of 4 inches to 1 foot in diameter, dimensions which are always available from the inferior classes of timber. More recently timber of even larger dimensions is in demand, as its cost of transport, &c., is less. At the same time, sound timber, free from knots and branches, is required, and dead or half-dead material from thinnings is rejected. The wood intended for paper-factories is now usually converted in the forest into barked blocks about 6 feet (2 meters) long and 4 to 8 inches in diameter, which are stacked like cord-wood.

The enormous demand which has arisen for paper-pulp has been one of the chief causes of the destruction of large areas of private forests, for even moderate-sized poles can be thus utilized. In North America, during the three years ending in 1894, 200,000 acres of forest have been denuded to satisfy the demands of 210 paper factories.

[This industry has the advantage of utilizing much wood from thinnings, which might otherwise be wasted.—Tr.]

Paper-pulp is now-a-days prepared in various ways, among which the **mechanical** and **chemical** methods are those chiefly followed. These two methods give very different results as regards paper-manufacture, the product of the mechanical method, termed **paper-pulp**, being more granular, whilst that of the chemical method, termed **cellulose**, is more fibrous, and makes a better felt. The difference between these two products depends on their mode of manufacture, which will now be briefly described :—

(a) **Mechanical Manufacture of Wood-Pulp.**—The wood is barked, cut into pieces about a foot long, split, and freed by the chisel and augur from all knots and unsound defects. It is then ground into a pulp by a rotating stone, and subjected to a continual flow of water : the pulp is separated by a special contrivance from the coarser wood-splinters, and ground into a finer state of subdivision, freed from all superfluous water, and pressed under heated rollers into sheets of felt, in which state it is sold to the paper-manufacturers. Material thus produced is termed **white wood-pulp.** If before being ground, the wood is steamed under a pressure of two to six atmospheres, or merely steeped in boiling water, it yields **brown wood-pulp,** which is said to have longer fibres and to form better felt than the former. Wood-pulping machines were first constructed by Völter, in Heidenheim, and have since been greatly improved ; they require a large supply of water both as motive power and for manufacturing purposes.

In Germany, in the year 1892, the number of wood-pulp factories had risen to nearly 600, and consumed annually about 1,000,000 stacked cubic meters (35,000,000 stacked cubic feet, or 700,000 loads) of wood, and produced 200,000,000 kilos (200,000 tons) of wood-pulp. In Austria-Hungary, in 1890, there were in active work 200 wood-pulp factories.

(b) **Manufacture of Cellulose.**—This manufacture is of two kinds, depending on the use of caustic soda or calcium-sulphite to macerate the wood. The present tendency is greatly in favour of the latter process.

Where soda is used, the wood, freed from bark, knots and defects, is cut by a machine into splinters about 2 centimeters thick, which are passed between grooved rollers working like a coffee-mill, and reduced into fragments 2 centimeters long and 5 to 8 millimeters thick. These fragments are then packed in perforated sheet-iron vessels, which are placed in a long horizontal steam-boiler. When the boiler has been filled with the vessels, its cover is fastened down air-tight, it is pumped full of a solution of soda, and boiled over a furnace. After three or four hours, the boiling, which is conducted with a pressure of about ten atmospheres, should be stopped, and the boiler emptied. The rough cellulose is then washed, sifted, bleached, and rolled by several hot-water drying-rollers, from which it is finally wound off in the form of sheets of felt, which are then sold. The residual liquid yields 75 to 80 per cent. of the soda, which may be used again.

When calcium-sulphite is used, the wood similarly prepared, as in the soda process, is placed in large boilers containing a solution of sulphite of lime, and boiled for fifty or sixty hours under a pressure of two and a-half to five atmospheres. The calcium-sulphite is prepared in tall towers filled with limestone, through which passes sulphurous acid, produced by roasting iron pyrites, and this passes through raised cisterns of water. The solution of calcium-sulphite thus formed is collected below in reservoirs. The wood-pulp which comes out of the boilers consists of soft, crumbling, reddish-yellow pieces, which are pounded, washed and mixed with water, passed through sieves, and pressed by heated rollers into felt, in which condition it is usually sold.

In Kellner's electrical process for preparing cellulose, wood is boiled in solutions, chiefly of common salt, and during the boiling is subjected to electrical discharges which effect the separation of the fibres. The economic value of this method has not yet been ascertained.

There are now about seventy cellulose-factories in Germany, which use annually about 700,000 stacked cubic meters (say, 500,000 loads) of wood, and produce 80,000,000 kilos (80,000 tons) of cellulose. A cubic meter of cellulose yields 4 cwt. of paper. In Austria-Hungary, in 1890, there were about thirty cellulose factories in full work. [Bamboos make excellent wood-pulp.—Tr.]

Of all the different preparations of wood-pulp, the cellulose prepared by the calcium-sulphite method is preferred, and is much cheaper than the soda method. The mechanical method is, however, cheaper than either. In all these industries, and especially in the mechanical method, there is now-a-days an excess of production over demand.

2. *For other purposes.*

Wood-pulp is used for many other purposes besides paper-making, sometimes usefully, at other times with doubtful advantage. Cellulose, for instance, is used in making numerous kinds of ornaments and furniture for dwelling-rooms. Even casks, tubs, vases, laboratory and cooking utensils, are thus made; also boats and rafters, underground tubes for telephone wires, oars, door-panels, &c. The spokes of railway-carriage wheels have been replaced by frames which are filled with cellulose. Antiseptic cellulose of silver-fir wood is used for surgical bandages. It is also used for carpets and wax-cloth, and as packing-material, especially in packing gunpowder, and for many other purposes. It is used for insulating electrical conductors, and successful attempts have been made to spin artificial silk from cellulose, and to use it as gun-cotton. As compared with paper-making, however, these other uses of wood-pulp are only of subordinate importance.

Quite recently Wendenburg has attempted to utilize coniferous cellulose and sawdust by means of dilute hydrochloric acid and a boiling solution of common salt, as a fodder for cattle, to the extent of 40 to 70 per cent., instead of straw or chaff. This method has not, however, met with much success. On the other hand, the great scarcity of fodder, in 1893, has caused an attempt to be made by Ramann to use green wood as fodder, and this has proved much more promising than the former experiment. The young twigs of broad-leaved trees up to 2 centimeters thick, which are known to be rich in reserve nutritive material, are cut up into chaff in a special machine, and pressed into a fermenting mass. About ½ to 1 per cent. of malt is then added, also some salt, and by damping it whilst fermenting, the heat is kept up to 140° F., and it is then cooled and used as fodder. This process converts the contained starch into sugar. This material has been favourably experimented on in several landed estates, and is considered equal to hay of average quality, and better than straw, and is liked both by cattle and horses.

3. *Saw-Dust.*

Although saw-dust, which collects in large quantities at saw-mills, is chiefly used as fuel, or as litter in cattle-stalls, or mixed with coal-dust to make the well-known **briquets**, it is also used for making water-tight parquetry floors, for sculptures, plates and other articles.* [In N. America for illuminating wood-gas.—Tr.]

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* Laris, Handelsblatt für Walderzeugnisse, xi. No. 4, and xii. No. 37.

SECTION XVII.—WOOD FOR AGRICULTURAL PURPOSES.

A considerable amount of wood is used in agricultural industries. These products have one character in common, being used more or less in the rough, or at least without any elaborate preparation. The following comprise the chief classes :—

Pea-sticks, consisting of twigs 1–3 years old from various broad-leaved species, especially beech and birch, and are the tops and branches of poles and trees which are cut off after fellings, in lengths from 2 to 4 feet.

Bean-sticks are used for scarlet-runners and other climbing beans; they are poles 8–10 feet long, and up to about 1½ inches thick at the base. Coniferous saplings or straight coppice-shoots of broad-leaved species are chiefly employed for this purpose.

Stakes are intermediate in thickness between bean-sticks and hop-poles, and are used for all kinds of purposes, chiefly to fill gaps in hedges and fences. They are generally coniferous saplings and smaller poles. Stakes are also used for tightening the chains and ropes used in lading timber and firewood on to carts. Saplings and small poles of different lengths of oak, ash, birch, beech, &c., are thus used.

Hop-poles, for use in hop-gardens; light, straight and slender coniferous poles are chiefly employed. [Sweet chestnut coppice also yields excellent hop-poles, and has been largely and profitably grown in Kent and elsewhere for the purpose.—TR.]

Hop-poles are usually placed in 4–6 classes, according to their dimensions, being from 16–40 feet long, and from 2½–5 inches thick at the base. They are generally barked in order to render them more durable. The introduction of steel-wire between wooden supports has replaced hop-poles in many localities, and reduced considerably the demand for the latter.

Tree-stakes, which serve as stakes for freshly planted orchard-trees, and in Germany usually consist of coniferous poles cut into lengths of 10–20 feet. Old (red) aspen-wood, robinia and other broad-leaved trees (ash, &c.) are also employed for this purpose.

[**Hurdle- and crate-wood.**—Much split ash, oak and other coppice-wood is used in Britain for hurdles, and for crates used in packing machinery, crockery, &c.—TR.]

Tree-props, which are used to prop-up the boughs of orchard trees when heavily laden with fruit, are usually of the same dimensions of small or middling sized hop-poles, and are made from poles of conifers, also of beech, oaks and other trees, several stumps of branches being left at their tops to serve as forks and support the laden branches.

Vine-stakes, which are placed in the ground close to vines and to which the latter are tied, usually consist of split oak or coniferous wood, 6–8 feet long, and 1½–3 inches square. In Alsace, vine-stakes are split from sweet chestnut stool-shoots 10–12 feet long; they are far more durable than oak-stakes. In France, vine-stakes are made even of aspen and willows.

Wherever, as in parts of the Palatinate, the vines are grown very low, and spread more horizontally than vertically, the stakes are left in the ground over winter, and only oak, sweet chestnut and robinia-wood are found serviceable. In this case, horizontal pieces or bars of wood are nailed across from one stake to another, the latter being placed vertically into the ground. The stakes are thick split pieces 4–6 feet long, and the bars split laths 10–14 feet long, which are split off straight-grained stems with a wedge or divider. They are sometimes replaced by steel-wire.

Wooden Park-palings.—These are employed round gardens and parks, and especially in Alpine pastures, and are made by splitting round logs 4–6 feet long. Inferior kinds of wood are used sawn and generally creosoted. They may be driven directly into the ground side by side. [In Britain, are generally nailed to strong post and rail supports, and kept entirely above ground, the lower part of the fence being formed by a plank placed horizontally from post to post. Deer-parks require the strongest fencing, and split oak and sweet chestnut, or sawn larch or Scotch pinewood are chiefly used.—Tr.]

Withes for fastening faggots, bundles of corn, oak-bark, hemp, &c., are made of coppice-shoots of hazels, willows, and different shrubs; sometimes oak and beech saplings are stolen for the purpose.

Brooms are usually made of young shoots and twigs of birch trees, and should be cut before the foliage has appeared.

Vigorous birch trees afford the best shoots for brooms. Brooms are also made of broom, *Genista*, peeled osiers, &c.

[In India large quantities of prickly bushes are used annually for making temporary dead fences round the crops in the dry season, and are used for fuel, or left to rot, when the cattle come into the fields to graze on the stubble after the harvest in April.—Tr.]

Subdivision II.—Firewood or Cordwood.

It might be imagined from the manifold uses to which timber is put, and which have just been described, that nearly all the wood produced by forests is thus utilized. Further on in this book the relative quantities of timber and firewood produced by forests will be discussed, but it should now be noted that firewood still forms a large portion of forest produce.

Next to food and clothing, fuel is, in temperate regions, the most indispensable material for humanity, for protection against the cold, cooking food and manufactures. Other fuels however, coal, coke, &c., compete with wood-fuel and reduce its price, so that every forest-owner should devote more and more attention to timber, the value of which is steadily increasing. We are not yet able, however, to dispense with wood-fuel, which (in Germany) still competes fairly with coal, and is preferred in many countries. As regards the various modes of consumption of firewood, the following classification may be adopted:—

1. *Firewood used for its Heating Power.*

In this case, wood is either **totally consumed** at one time, or is first **partially consumed** and converted into **charcoal**, a more serviceable form of fuel than firewood, which is also used for heating purposes.

Firewood is chiefly burned directly for heating apartments, or for cooking food, washing, drying, &c. Hardwoods which give out a more lasting, uniform heat than softwoods are preferred to the latter for the above household purposes. For boiling food or heating boilers, as in kitchens, hard dense woods are preferred; for baking or roasting, when a quick intense heat is required, porous softwood or charcoal is preferable. It is not always possible, however, to obtain the best material, and wood of all kinds is used for both purposes.

Firewood is still employed in factories, which may be classified according as they require **hardwoods**, as in soap-making, laundries, and all factories employing boilers; or **softwoods**, producing a quickly radiating intense heat, as in bakeries, potteries, brick-kilns, lime-kilns, &c; finally **charcoal**, the heat of which is not only quick and intense but also very enduring, as for the work of locksmiths, blacksmiths, glass-makers, &c.

The carbonisation of wood is described in the third part of the present work. [Charcoal of alder, dogwood, &c., is used in making gunpowder.—Tr.]

2. *Combustion of Wood in order to produce certain Substances which are either Intermediate or Residual.*

The **intermediate** substances are obtained during wood-carbonisation, as for instance pyroligneous acid, wood-gas, tar, pitch, lamp-black, &c.; the **residual** substances remain after the wood has been more or less completely consumed, as for instance potash, &c.

The manufacture of pyroligneous acid, which is used to form several chemical compounds, has in many places been undertaken on a large scale. Woods which yield the best fuel are most productive in this respect, and above all those of beech and birch. A cord (216 cubic feet) of sound beechwood will yield 25 cwt. of distilled products (tar, acetic acid, water, &c.), and 1½–2 cwt. of pyroligneous acid.

Most illuminating gas is made from coal, but exceptionally from strongly resinous red pinewood [in N. America from sawdust.—Tr.]. Wood-gas can be more easily and thoroughly purified than coal-gas. Although tar is obtainable from all kinds of wood, broad-leaved woods are less suited and far less productive than conifers. Red pine and spruce are chiefly employed. In the north of Europe, in some forests, the whole stem of these trees is thus utilized, and the trees are stripped standing of all their bark, except a small strip in order to enhance the flow of turpentine. In other forests, where timber is more valuable, only pine-roots are thus utilized, and these only rarely, as coal-tar has almost driven wood-tar out of the market.

In Sweden attempts have been recently made to utilize tar-oil mixed with benzine for lighting purposes. It is very doubtful whether alcohol will ever be distilled cheaply from wood.

Pitch[*] is prepared by melting crude resin in iron pots over a steadily increasing, but at first slow fire. The melted resin is at first yellow, then brown, and lastly becomes converted into black pitch. In order to expedite the process, and increase the out-turn of pitch, a press is used which fits into the pot, and is moved forward by means of a screw. The refuse after the pitch has been pressed out is used for making **lamp-black.** The forester has, however, little to do with any of the above-mentioned industries.

It is evident that compared with timber it is unimportant in what form firewood is used for burning, or other purposes. As a matter of fact, split and round billets, root-wood, and bundles of faggots of the most variable kinds are so used. The dimensions in which firewood is delivered for different purposes are the most important items, and it may here be remarked, with reference to later paragraphs on that subject, that a minute sub-division of fuel-trees is generally most advisable. A rough reduction in size is first undertaken in the forest, and the consumer completes the process before using the wood.

Sub-division III.—Woods arranged according to their Uses.

In the following abstract of the technical uses to which wood may be put, only its uses as timber are considered. The list first contains the European woods, and then the most serviceable foreign woods.

1. *Woods of Broad-leaved Trees.*

Oakwood.—Used in logs and balks for superstructures, hydraulic works, bridges, ship and boat-building, gate-posts; as scantling and boards for mill-wheels, railway-sleepers, mining timber, joiners' work, cabinet-making; for wheelwrights' work, blocks, staves, bungs, sieve-frames, shingles, trenails, wood-carving, pianoforte-making, turnery, window-frames, park-palings, vine-stakes, hurdles, &c.

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[*] Karl Georg Miller, Die trockene Distillation, Leipzig, 1858. Ad. Hohenstein, Die Teerfabrication, Wien, 1857; Ditto, Die Pottaschefabrication, Wien, 1856. Joh. Bersch. Verwertung des Holzes auf chemischen Wege.

It should be noted that the fine-zoned, easily worked, softer wood of the sessile oak is preferred to that of pedunculate oak for all purposes making less demands on size, hardness, strength and durability. The latter is preferable for constructions of all kinds, for staves, wheelwrights' work, split-wood, &c.

Ashwood.—For pillars, stamping hammers, wheelwrights' work, joinery implements, tool- and whip-handles, hurdles, barrel-hoops, gymnastic apparatus, lance-shafts, rudders and oars. Figured ash-wood is greatly in demand for furniture.

Elmwood.—Used by the furniture-maker, undertaker and turner, greatly in demand by the wheelwright; for blocks and the inner lining of ships. Figured elmwood is much esteemed; the wood of the common elm is generally more valuable than that of the mountain elm.

Sweet chestnut.—Used occasionally in superstructures, also for furniture, gate-posts, park-palings, staves; makes excellent vine-stakes and hop-poles.

Sycamore and **maple.**—Preferred by the cabinet-maker for solid and veneered articles, parquetry, &c.; by the turner and carver; for articles made by the compass-saw, churns, musical instruments, gunstocks and ornamental whip-handles. Figured sycamore is very valuable [and so is bird's-eye maple.—Tr.]

Limewood.—For fine carving, founders' patterns; used under veneer, for turnery, in pianos and organs, wooden shoes, papier-mâché, &c.

Beechwood.—Joinery, for floors and staircases, in mills and mines (stamping-hammers), railway-sleepers, street-paving blocks, cabinet-making; for bentwood furniture, pianos, carpenters' benches, wheelwrights' work, slack barrels, agricultural implements, packing-cases; for coarse carved work, wooden shoes, horse-collars, gunstocks, brushes, &c.

Hornbeam-wood.—Wheelwrights' work, in mills, machinery, turnery, shoemakers' pegs and lasts, plane-boxes, carpenters' benches, tool-handles, agricultural implements, &c.

Birchwood.—Joinery, furniture, wheelwrights' work, turnery, bobbins, wood-carving, brushes, clogs, shoe pegs, coarse carved wares, withes, brooms, &c. Figured birch-wood much prized by cabinet-maker.

Alder-wood.—Used underground in mines, for covering damp places, water-conduits, largely used for cigar-boxes, clog-soles, rarely carved.

Poplar.—Rafters and rails, joinery and wheelwrights' work, packing-cases, coarse carving, matches, cigar-boxes, and papier-mâché. The white poplar, or Abele, also for superior wood-carving and in organs. Aspen for lucifer-matches.

Willow.—Cricket-bats, basket-work, withes, fascines; wood of tree-willows used in furniture under veneer, for packing-cases, papier-mâché. [Being soft and tenaceous is used as well as poplar for lining carts.—Tr.]

Robinia (False acacia).—Wheelwrights' wood, implements, joinery, trenails, vine-stakes, tool-handles and turnery.

Service-wood (*Pyrus torminalis*).—Used by turner and cabinet-maker, and for wood-carving.

Rowan-wood (*Pyrus aucuparia*). — Splendid wheelwrights' wood, on account of its great toughness.

Hazel.—Used for hoops, sieve-frames, and also by the cabinet-maker.

Horse-chestnut.—Used by the turner and cabinet-maker, and for fine wood-carving.

Wild cherry (*Prunus avium*).—Esteemed by the cabinet-maker and turner, and used by the wheelwright.

Wild pear (*Pyrus communis*).—Highly esteemed for cabinet-making and turnery, for picture-frames, blocks for woodcuts. Figured wood equally prized with that of the cultivated pear and apple-trees for veneers.

Walnut.—Highly esteemed for furniture, veneer, gunstocks, and for frames, wood-carving and turnery.

2. *Coniferous Woods.*

Spruce.—Logs used in construction of all kinds, and in boats for fresh-water traffic. Sawn timber used by the joiner and cabinet-maker, by the wheelwright and shingle-maker, for boxes, packing-cases, toys, piano-making and organ-building. Poles and saplings used for agricultural purposes, ladders, telegraph-posts, fencing, vine-stakes, wooden baskets, and paper-pulp.

Silver-fir (*Abies pectinata*).—Used for the same purposes as sprucewood, and especially useful in buildings, and for pillars, and also in hydraulic works.

In some European districts silver-fir wood is less prized than sprucewood, partly on account of its darker colour, and partly because much of it that comes to the market is too old and knotty, so that it cannot be planed as easily as the wood of spruce. [When both are grown in Britain, silver-fir is superior to spruce.—Tr.]

Scotch pine (*Pinus sylvestris*); also termed **red deal.**—Used for the same purposes as spruce, except for musical instruments, shingles and other split-ware; superior to spruce or silver-fir for hydraulic works (piles), bridges, or mining timber; used for railway-sleepers and all purposes requiring durability; esteemed for ships' masts and spars, spars for windmills, conduit-pipes, street-paving, &c.

Larch (*Larix europæa*).—Used for the same purposes as red deal, and wherever durability is demanded is more highly esteemed than the latter.

Black pine (*Pinus Laricio*).—More used in hydraulic and earthworks than for superstructures, furniture, &c.

Weymouth-pine (*Pinus Strobus*), termed white deal in America. —Used in superstructures, especially in roofs; also in cabinet-making, packing-cases, &c. Old wood is preferred.

Cembran pine.—Used for wood-carving, toys, and cabinet-making.

Yew (*Taxus baccata*).—Esteemed for bows, cabinet-making, wood-carving and turnery.

Mountain-pine (*Pinus montana*).—Turnery and wood-carving.

Juniper (*Juniperus communis*).—Fine wood for turnery and wood-carving.

3. *Exotic Woods.*

Teak (*Tectona grandis*).—The best wood for shipbuilding, superstructures; largely used in railway-carriage-building, and by the cabinet-maker, wheelwright and turner.

Mahogany (*Swietenia Mahogani*).—Highly-esteemed furniture-wood; also used for panels, picture-frames, cigar-boxes, &c.

[**Padauk** (*Pterocarpus indicus*) from Burmah and the Andaman Islands. Highly esteemed for railway-carriages and cabinet-making.—Tr.]

Hickory (*Caria alba*).—Highly esteemed in carriage-making, and for handles of implements.

Ailanthus glandulosa.—Recommended for carriage-making, on account of its strength, elasticity and non-liability to warp.

West Indian cedar (*Cedrela odorata*).—Best wood for cigar-boxes, and in the construction of river-, pleasure- and racing-boats.

Box (*Buxus sempervirens*). — Used for wood-engraving, spindles, turnery, flutes and other musical instruments, measures, shuttles, &c. The wasteful exploitation of box-forests around the Black Sea and in Persia is causing this valuable wood to become rare. [There is, however, a considerable area of box-forests in the Indian Himalayas.—Tr.] Dogwood and black-thorn have been tried as substitutes for box-wood.

Ebony (*Diospyros Ebenum, D. Melanoxylon* and other species).—Turnery and wood-carving, pianoforte keys, knife-handles, &c. [Stained holly used to imitate ebony.—Tr.]

Lignum-vitæ (*Guaiacum officinale*).—Bowls, sheaves for pulleys; used in gunpowder-manufacture as grinding-rollers.

Jacaranda (*Jacaranda brasiliensis*).—Turnery, inlaid furniture, &c.

Rosewood (wood of several species).*—Furniture, pianoforte-making, &c.

Granadilla (undetermined wood from Honduras).—Used similarly to rosewood, and for flutes.

Horseflesh-wood (*Cæsalpinia sp.* from Bahamas).—Violin-bows, machinery.

Greenheart (*Nectandria Rodiæi*, lauraceous tree from South America and West Indies).—Ship-building.

Violet-wood (undetermined West Indian tree).—Inlaid furniture, &c.

Satinwood [wood of different species of trees, among others *Chloroxylon Swietenia*, from Ceylon.—Tr.] Used for furniture and the backs of brushes.

Olive-wood (*Olea europæa*).—Wood-carving, &c.

Quebrache-wood (*Aspidosperma Quebracho*, from Argentina).—A good substitute for boxwood, for wood-engraving.

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* *Vide* Laslett, *op. cit.* p. 284.

Briar-wood (*Erica arborea*).—Roots used for tobacco-pipes.

Pencil-cedar (*Juniperus virginiana* and *J. bermudiana*).—For lead-pencils, pianoforte-hammers, pipe-stems, turnery and finer cabinet-making.

Pitch pine (*Pinus australis*, from the southern States of North America).—Splendid architectural wood, resembles the best larchwood in durability; ship-building, railway-carriages, less used for furniture.

The name "Pitch pine" is used in a misleading way, inferior species, such as *Pinus rigida*, having been thus imported into Germany; [the wood of *Pinus australis* is, however, very largely used in Britain.—Tr.]

American cypress (*Taxodium distichum*).—Used for door- and wall-panelling, &c.

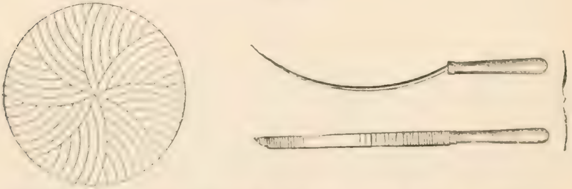
Oregon or **Douglas fir** (*Pseudotsuga Douglasii*).—Used in superstructures, and for shipbuilding; also as scantling in joinery.

As this tree has a wide range in North-western America, it is evident that the quality of its timber varies considerably. When grown at a moderate elevation near the Pacific Ocean, it is said to be most durable and valuable.

[The wood of many Australian **gum-trees** (*Eucalyptus sp.*) is highly esteemed: thus "Jarrah" (*E. marginata*), ship-building, railway-sleepers, wood-paving; and "Kari" (*E. diversicolor*), wood-paving.—Tr.]

[**Lancewood** (*Duguetia quitarensis*, Benth. of Guiana, and *Gualteria virgata*, Brazil? which is largely used for fishing-rods, golf-clubs, &c., should also be mentioned.—Tr.]

Fig. 19.



Conversion of sprucewood into staves in the Jura. (After Boppe.) *Vide* p. 147.

CHAPTER III.

FELLING AND CONVERSION OF TIMBER.

The third chapter of this book deals with the methods of felling trees, and converting them into logs and scantling which are then handed over to the consumer.

When one considers the long period which elapses from the seedling stage of trees till their maturity, and the many dangers to which they are subject, and compares this with the few weeks required to convert them into marketable lots, it would appear that the conversion of timber is a very simple undertaking, within the comprehension of an ordinary woodcutter. In many cases this is so, and where pure woods producing firewood in plains or low hilly districts are managed according to the clear-cutting system with artificial reproduction, conversion is nothing more than a clean sweep of the old wood, and cutting the trees into convenient sizes for export. But wherever natural regeneration is employed, and the woods are uneven-aged and of mixed species; where the best qualities of timber are required, and each tree is to be utilized so as to afford the most valuable material it is capable of yielding, so that the forest may give the highest possible revenue and the cost of conversion be reduced as low as possible; where the locality presents all sorts of difficulties, and successful working can only be assured by employing clever woodmen:—in all such cases, the mode of conversion adopted is of such importance, that the revenue of the forests, their regeneration, and tending, depend chiefly on the way it is carried-out.

The foremost rule in conversion of timber is also common to all industrial undertakings, and is as follows:—Consider carefully the uses which may be made of the raw material, and then act as far as possible without wasting it, and in accordance with the current demands of the market.

Since the produce of every forest comes under the influence of a special market, the wares required by which are multifarious, while local requirements, customs, and usages are also influential, there must be many modes of conversion suitable for different localities. In the following sections, therefore, the results of experience are considered, their utility gauged, and a decision formed as to the basis of a rational system of Forest Utilization.

SECTION I.—MANUAL LABOUR.

1. *General Remarks.*

The productiveness of every industry depends on the number of available labourers, and on their skill and mode of organization. Hence, the essential conditions for profitable forest utilization are plenty of good woodcutters, and good arrangements for furthering their labour.

The worth of a woodcutter does not depend only on the value of the material which he can convert in a given time, but also on his following the rules of Sylviculture and Forest Protection.

In all forest management based on the highest possible pecuniary return, which may be termed **Economic Forestry**, it is in Germany a general rule to entrust the fellings to woodcutters under the pay and control of the forest owner, and only exceptionally to employees of wood-merchants. The latter method was formerly more frequent, and is still largely followed in France and Britain, and occasionally in Germany.

Speaking quite generally, whenever the sale of the wood will do little more than cover the cost of its conversion, timber-exploitation may be left to the purchaser of standing trees, either by the sale of all standing trees on a certain area in block, or by single marked trees. In high mountain-districts there are localities difficult of access, where the conversion and transport of timber would frequently cost more than its value, if done by other agency than that of the timber-merchant, such as State agency, or that of a private forest owner. In such cases it is better to sell the trees to a merchant. Where timber has to be given away to right-holders, in cases where only inferior material is in question and there is no fear of the right-holders defrauding the forest owner by taking too much produce, it is also better to allow them to fell and convert the trees. In forests belonging to poor communes, or villages, it may be more economical for the villagers to work-out the timber for themselves.

In all these cases restrictions for the benefit of the forest must be imposed on the woodcutters, just as if they were directly under the control of the forest owner.

It is evident that only by the employment of woodcutters engaged and paid by himself can the forest owner maintain a satisfactory and permanent labour-force, and this he should always endeavour to secure. Such an object, however, is not always attainable, and though occasionally it may be easily secured, it is sometimes very difficult to do so. This depends on local circumstances, and especially on the superfluity or want of labourers, the duration of work in the forests, and the conditions of employment offered to the labourers by the forest owner.

The **Demand for Forest Labour** fluctuates with the season of the year. Owing to increased production of wealth, to modern laws regulating industry, and to the rapidly improving means of transport, the conditions of labour have altered considerably during the last twenty years, and forestry has not remained unaffected. The woodman who formerly remained attached to his hamlet has freed himself from his fetters; he leaves field and forest, and proceeds to the centres of industry and manufacture, where he hopes to get a better price for his labour, to lead a pleasanter life than in his lonely forest village, and to acquire property more rapidly. A few years ago, owing to this migration of the villagers, the scarcity of labour in certain forest districts had become calamitous. The crisis, however, did not last long, and at present, many woodmen have returned to their former pursuits.

The **Duration of Work in the Forest** depends on the local extent of the forest area, and the degree of intensity of forest management. Whenever there is always full employment throughout the year in an extensive forest district, the inhabitants are closely attached to the forest. In such districts there is hardly any other industry but forestry; and, even if other employment could be found for the men, outside or within the district, yet, provided they can earn the usual wages prevailing in the locality, forest work is preferred to any other industry by the greater part of the population, who have, as it were, grown-up in mind and spirit with the forest. Where, on the contrary, in districts chiefly industrial or agricultural, the work in the few existing forests can be done in a few weeks' time, forest work is only an auxiliary to the usual modes of occupation, the labourers have for it little taste or skill, and can be induced to work only in a perfunctory manner.

The **Remuneration and other Conditions** which the woodmen receive from the forest owner should under all circumstances be a fair equivalent for the amount of labour required, and suffice for the support of a labourer and his family. It is, therefore, clear that the more a forest owner can identify his own interests with those of his woodmen, the more remunerative will be the management of his forest.

2. *Demands on the Woodcutter.*

People are apt to think that the demands made on a woodcutter may be satisfied by any labourer who can use the axe and saw. This is indeed true in certain cases, but usually a certain amount of skill, foresight, power of reflection and experience is required, attainable only after prolonged labour in the forests, which all workmen are not equally capable of acquiring, and is not found in an equal degree in all forest countries or districts.

All industrial operations are more or less dependent on the skill of the workmen employed, and the demands which forestry make on labour form no exception to this rule. It is, therefore, necessary to distinguish woodcutters of different grades of utility, and to distribute the work among them according to their capability. Whilst for work in high forest, clear-cuttings, coppices or thinnings, the ordinary labour force may suffice, natural regeneration-fellings and cutting of standards over underwood demand much more skilful hands.

There is a great difference between working forests for fuel, or for valuable timber and where a careful and detailed mode of converting the timber is required.

Besides the demands made on skilled labour by special conditions of forest management, which vary with the locality, there are others of a general nature which must be made on every woodcutter, or gang of woodcutters, as regards order, capacity for labour, and control. A consideration of these points leads to a statement of the **conditions of agreement** between the labourer and the forest owner, which should be thoroughly explained to every woodcutter before he engages to work in a forest. Although these conditions vary for different forests, or localities, in order to provide for important local requirements, there are others which prevail throughout a whole province or country. Such **general conditions** are, therefore, usually decided for extensive forest tracts, leaving the **special local conditions** to be added where necessary, **penalties** for breach of agreement being included.

The following are the usual clauses in an agreement with a woodcutter:—

General Conditions.

A. Obligations of the Woodcutter.

(a) Regarding his conduct during the engagement.
(b) Regarding felling.
(c) Regarding conversion of timber.
(d) Regarding removal of the timber.

B. Obligations of the Wood-Stacker, and of the Foreman.

C. Obligations of Men employed in Carrying and Floating Timber.

D. Obligations of the Contractor.

E. Special Conditions.

F. Penalties.

A. Obligations of the Woodcutter.

(a) **Conduct of Woodcutter.**—As regards the conduct of the woodcutter, the following are the chief points:—

i. No one is allowed to do other than the special work allotted to him.

ii. Every woodcutter must be at work punctually at the appointed hour, and should work steadily and without intermission until the work is completed, except during the off-time agreed upon.

iii. Any woodcutter absent without permission from work will be warned on the first occasion, and on the second will be considered to have vacated his work of his own accord.

iv. No work is to be done before sunrise or after sunset.

v. Every woodcutter is to provide his own tools in good condition, and he should also have a two-foot rule. Wood for mending tools and for constructing huts for the workmen is provided by the forest guards. When the work is completed, all wood used for huts, timber, sledge-roads, &c., should, as far as possible, be converted into firewood.

vi. Every woodcutter should be as careful as possible in carrying out sylvicultural rules, and obey the special instructions of the manager and guards in this respect. He is also held responsible to report any infractions, which have come to his knowledge, of such rules by any other workmen.

vii. The woodcutter is not allowed, either by himself or his family, to remove any wood from the felling-area. At the completion of the felling and conversion of the produce, all broken pieces, chips, and other wastage, will be divided among the workmen.

viii. Each foreman is responsible for the security of the wood worked by his own gang.

ix. Fires should not be made by less than six workmen, wherever a larger number is present on a felling-area. Great care must be taken of the fire, and it should be extinguished, or carefully guarded, every evening.

Rules under headings B to E as regards felling, conversion, and removal of the timber will be given in the next chapters dealing with these subjects.

F. PENALTIES.

The third part of the conditions of agreement gives the penalties for infraction of any of the above stipulations.

Such penalties may be pecuniary, such as deductions from wages, temporary suspension from work, or dismissal, and whenever the woodcutter obtains certain privileges from the forest owner, such as land for cultivation, wood, litter, &c., temporary or permanent deprivation of such privileges.

Certain offences by woodcutters and other forest labourers are punishable under the forest law.

The penalties should be those usual in the district, and within the means of the working population.

Deductions from wages and deprivation of privileges are the most suitable penalties for the poorer workmen. Wherever experience shows that penalties are unavailing, it is better not to include them in the conditions of agreement, for in such a case it is better to have no law than one which cannot be carried out. There are many districts where at present this is the case, and penalties cannot be enforced owing either to the poverty of the people or the scarcity of labour.

3. *Wages.*

(a) **General Remarks.**—The remuneration to the woodcutter for his labour consists chiefly in a regularly contracted payment, but partly in undertaking to contribute to his support or that of his family in cases of accident, sickness, undeserved want, &c., and occasionally in special rewards paid to skilled labourers for difficult and unusual work.

One of the best means for retaining the services of the better part of the labourers for forest work is to allow them certain forest privileges gratis, or at reduced rates, such as small areas of land for cultivation during good behaviour. Societies for saving money, to which the forest owner contributes in proportion to the regular contributions by the labourer, may also be mentioned here.

Among all these items the wages are naturally the most important, and these may be either **contract-wages** by the piece, and proportional to the amount of work done, or merely **daily wages**, reckoned by a fixed number of hours daily during which the workman is employed: as a rule, daily wages are exceptional in woodcutters' work, and are given only when the amount of trouble taken by the workman is out of all proportion to the amount of work done, as in forest plantations, where if the work be paid by the number of plants, the latter will be planted carelessly, without proper attention to their roots.

A piece of work done, or unity of work, may be measured in various ways, either by its weight, volume, or roughly stacked volume; or by the chief determining measure of the work, as for instance, the length and mid-diameter of a log, the yard of ditching, the hundred planting-holes of definite size, the single railway-sleeper, &c. Weight is not much used in forestry as a unit of work, but the common unit for timber is the cubic foot, or load of 40 cubic feet, for hardwood, and of 50 cubic feet for softwood, both corresponding roughly to a ton. Stacked firewood is measured by the cord (6 feet × 6 feet × 6 feet) of 216 stacked cubic feet, and faggots by the hundred.

Timber may be measured by its dimensions, and the diameter of different pieces may be used as a unit. Such a measurement of his work is more easily appreciated and calculated by the woodcutter than when the cubic foot is the unit for measurement, and it is also a fairer measure of the work done than the latter. It has not yet been decided whether it is more profitable, or not, for the forest owner to measure the work for payment by the diameter of the piece, or by the cubic foot, but experiments made in Saxony are in favour of the former system, which is much the commoner of the two. Wherever logs are sold by their length and the diameter of their smaller end, these latter should also be taken as the units of work.

Whatever unit of work may be chosen, the unit of pay must now be calculated, and this naturally varies more or less with the time and locality, and depends chiefly on:—the supply of labour; the extent and variability of the demands for labour in a district for manufactures, agriculture, public works, traffic, &c.; the immediate cost of the necessaries of life; the value of money measured in commodities; the economic condition of the people; the inclination of workmen for forest work, &c. Different measures may be taken to rectify the greater or less variability of the circumstances which affect wages. Either a permanent table of average wages is compiled, the wages being increased or diminished when necessary, or new tables of wages may be prepared annually, according to the price of labour. In the latter case a written agreement to hold good for a year between the forest owner and the workman must be made, and signed by both parties.

Besides the fact that it really furthers economy to secure fair wages to the workman, it is also clearly in the interest of the forest owner, as contented workmen will avoid waste in felling and converting timber, and damage to young growth. Care for the welfare of the forest depends more or less directly on the woodcutter's work, and the latter will always turn the rate of pay to his own advantage. The amount of care he takes of the forest will be always the less, the lower his wages are driven by the competition of other workmen.

In forest management, as in all great productive industries, the determination at any time of fair rates of wages is of the greatest importance, and the question then arises, how should this be done?

(b) **Determination of Rates of Wages.**—It is clear that the woodman must obtain as high wages in the forest as he could get by a similar expenditure of labour in any other rough industry. The forest owner has to compete for his labour with other industrial enterprises; he may usually compete with them successfully when he remembers that the industrious woodcutter should receive wages somewhat above those actually in force for other works in the district for the hard and frequently dangerous forest work in ordinary fellings. This addition to the ordinary local wage depends on the favourable or unfavourable aspect of the circumstances affecting wages which have been already described; it may be sometimes 10 per cent., 20 per cent., or even 30 per cent. above the usual daily wages of labourers. The amount of the daily wage once settled, the next step will be to fix the pay for each unit of work in accordance with it.

It is easy to ascertain from the results of the previous year's felling, what amount of work an industrious workman can do in a day, *i.e.*, how many cubic feet of converted timber he can prepare in summer in ten hours, and in six or seven hours in winter, and in this way, given the rate of daily wage, the rate per unit of work can be fixed.

There are, however, several classes of wood produced in each forest, and a distinction must be made between conversion of firewood and that of timber of different varieties. As regards firewood, it should be noted that split billets are frequently the predominating class. As regards classified timber, it cannot be predicted which class will predominate; this depends on the mode of conversion and the size of the trees, &c. Thus, in some districts, middle-sized butts for saw-mills—in others, average-sized logs—will be the material on which the wood-cutter bestows most of his labour, and for which the rate should be fixed. Firewood and timber are produced by all forests, so that there are two standards of rates of pay, of which one is for a cord of split firewood, and the other for a unit of that class of converted timber which the forest yields most abundantly.

(c) **Scale of Wages.**—The standard rates, therefore, consist in those paid for split-wood and for one kind of converted timber: but on every felling-area there are several — often many — classes of timber and firewood, the preparation of which does not exact the same amount of labour, or the sale-values of which are highly dissimilar; there must therefore be several grades in the rates of pay for piece-work. These different piece-work prices are always multiples, or parts, of the two standard rates of pay, and in their case the amount paid, besides being, as far as possible, proportional to the work done, should also be proportional to the sale-value of the converted material.

As regards the former of these factors (the expenditure of labour on any work) round billets are much easier prepared than split-wood, and should be paid for at a lower rate; whilst the preparation of 100 bean-sticks should cost less than that of 100 hop-poles.

The amount of labour involved in the work is, however, made subsidiary to the sale-value of the out-turn, and the maxim of making the labour-charge for preparation of more valuable material higher than for what is less valuable is of the highest importance. Thus, the preparation of the better classes of logs or scantlings is more highly remunerated than that of the lower classes, even when the amount of labour expended is the same in both cases; this is especially true for long pieces of valuable timber, provided the diameter at the small end is up to standard; a higher payment would be made for the entire piece than if it had been cut in two, although in the latter case more labour would have been expended.

There are forest districts where, in the interest of the forest owner, the wages of woodcutters are allowed to rise and fall with the sale-prices of the outturn; as in parts of the Schwarzwald, and especially in the forests of the Prince of Fürstenberg. The best plan is, therefore, to pay relatively the highest rates for those pieces, the sale of which is most profitable to the owner, and to pay the wages corresponding to the labour involved only for less saleable pieces, the number of which the owner wishes to keep as low as possible. Thus, payment for wood from the stump and roots of the trees is kept very low, to prevent material fit for straight, split, or round cordwood being thus used, and especially to keep down as much as possible the amount of root- and stump-wood.

(d) **Area where the Same Wages Prevail.**—Once the scale for labour-payments has been decided, it may be applicable to a forest district, range, or working circle, but sometimes only to a particular felling-area. Thus, where the locality is unfavourable, as, for instance, on steep, lofty slopes; in fellings where special care has to be taken of the material, or of the regeneration or tending of the forest; in very remote felling-areas, where the woodmen have far to go to reach their work; where the trees to be felled are far apart, so that there are difficulties in collecting and sorting the outturn; and in several other cases,—greater demands are made on the labourers than where opposite conditions prevail.

The preparation of forest accounts is much simplified when the same rates of payment are made in all the felling-areas of the same forest range. In level, uniformly-stocked forests, and especially where only one species of tree is grown, such simplicity is often admissible; but in the case of irregular woods and unlike conditions, the forest owner will find it to his profit to have different rates of payment for different localities.

Thus, we have various rates of payment for piece-work, which rise and fall with the local daily wage. In allotting these rate according to the different kinds of produce, too much detail should not be attempted, so that the accounts may not be too complicated. An exception to this maxim arises only in the case of forests yielding highly valuable timber.

(e) **Wages for Barking Trees, Stacking Firewood, &c.**—When the rates of payment for felling and converting the timber have been settled, it is also usual to enter in the agreement the rates for barking the trees, also for collecting the timber and stacking the firewood. The latter work usually involves only one rate, but in the case of collecting the timber in temporary forest depots, the greatest differences of rates, compared with the average rates for pieces of the same size, may prevail.

In level land, it is necessary to convey the converted wood only to the nearest road, or timber-depot, and the amount of labour involved is practically the same in all cases for pieces of similar dimensions; but in mountain-districts there are, as a rule, great differences in this labour, and it is usual to fix different rates for each felling-area at different altitudes.

(f) **Daily Wages.**—There are cases where special demands are made on the ability, experience and care of the workmen, which must be considered in fixing wages, for in these cases it is quite exceptional that the work is at all proportional to the energy expended on it. If in these cases a special agreement cannot be made, daily pay should be given. For constructing the various means of water-transport; making or repairing roads, slides, bridges; building substantial huts for workmen; setting-up fences, and so on, the skill of a carpenter or engineer is required, although it is frequently only a wood-cutter who does the work, and he should then be paid in proportion to his skill. Only experience can guide the forest manager in settling a fair wage for such work.

It is clear that the total amount of woodcutters' work in any forest varies according to the locality, the degree of conversion of the timber which is required, and many other circumstances, and that for each forest a special study of these factors is required. The most important of them are:—species of tree; age and character of the standing crop; suitability of the wood for special purposes; the kind of felling employed and nature of the locality; season of felling; distance from the woodcutters' homes and the industry and skill of the woodcutters.

4. *Organisation of the Labour-Gang.*

(a) **General Account.**—It is evident that the efficiency, as regards quality and quantity of outturn, of the whole force of labourers employed in a forest, leaving out of consideration their special aptitude for the work, will depend greatly on the supervision the foresters and forest-guards can exercise over them. This influence and the possibility of its leading to useful results, will depend on the relations of the woodcutters to one another, and on their dependence on the forest and its interests. All this varies considerably from place to place, and in certain cases it is hardly possible for the forest-manager to exert the desired influence, whilst in others he can do so quite easily. In order, however, to do what is possible in this respect and supervise the hundreds of woodcutters who may be employed in any forest-range, as well as distribute them suitably among the different felling-areas and pay them proportionally to their labour, a certain organisation of the whole force of labour must be instituted, subdividing them into gangs and parties, and appointing from amongst themselves certain influential persons as foremen and heads of parties. The gangs are usually composed of all men coming from the same village (or district), and their leader is termed a foreman. A party consists of the number of men, not less than 2 or 3, required for complete felling and conversion of a certain lot of trees. The party chooses its own leader, works together and divides the payment for the work done, into equal parts among its members.

Considerable importance should be attached to the choice of the foreman, as he is the intermediary between the workmen and the forest officials, and is more or less responsible during the absence of the latter for the conduct of the woodcutters. On account of the indispensable nature of his services it is advisable to attach him as much as possible to the forest and to keep him constantly employed; he should also get special privileges. He usually settles the accounts with the men, and obtains a small percentage of the total payment for doing so.

The connection of the woodcutters with one another varies in different places, depending partly on the possibility of carrying out the organisation already described, and partly on local laws regarding workman and employer. It is often very difficult to enforce penalties against the woodcutter for non-fulfilment of the contract, or agreement, made between him and the forest owner, although it may be advisable if possible to secure such an agreement. Whether an agreement is made with all woodcutters or with some of them only, or with the foreman on behalf of the other men, depends on the particular class of labourers to be dealt-with. Woodcutters may be classified as follows:—

(b) **Non-associated Woodcutters.** — Where forest blocks are found scattered amongst agricultural lands, forestry is only an accessory means of employment for the people, and no regular gang of woodcutters exists. The men engaged for forest-work are a motley crew following all callings and without any connection with one another. The attachment binding the woodcutter to the forest is in such cases generally of the slightest kind, and even if a legal act of agreement be made between him and the forest owner, it will be only of a temporary nature, depending on his own interest and liking for the work. In this class there is no association between the different woodcutters, each man works independently of the others, or they may work in pairs in the case of sawyers.

Very often such a gang of woodcutters is composed of quite different individuals at the close of a felling to those who commenced work on the same area. In such cases, if the forest-manager wishes to secure attention to the most necessary protective rules, he must make *a separate agreement with every labourer.*

(c) **Associated Labour.**—In extensive forest districts in plains and mountains the conditions of labour differ greatly from the above. The chief means of livelihood of the inhabitants are then obtained from the forest and the work it affords; the people consider it an honour for a man to be employed in the forest, and forest work is preferred to all others which may offer.

A few of the people possess all the best qualities of these woodcutters, and are most attached to the forest and most trustworthy in working, and have much influence over the other men. In such cases it is sufficient for the forest owner to make *legal agreements* with the more influential woodcutters when they are sufficiently numerous to form a regular enrolled gang constantly employed in the forest, and with a common insurance fund to which the forest owner contributes. Such a labour-gang is strengthened from time to time, as necessity arises, by temporarily engaging other men.

(d) **Contractors' Men.**—Sometimes the legal act of agreement is made by the forest owner with a contractor, who undertakes to supply all the men required for any definite piece of work in the forest.

Contractors are frequently active, influential and fairly wealthy men who have considerable tact in managing woodcutters. Their assistance simplifies matters for the forest owner, as the contractor has all the worry and trouble of managing and supplying the labour-gang, and of paying them in detail for the work done.

In extensive forest districts, insufficiently supplied with experienced foresters or forest-guards, or where the woodcutters are very experienced and trustworthy and the work can be largely left to them without much supervision on the part of the forest staff, it is often better to leave the conversion of the timber to an experienced contractor who thoroughly knows the capacity of individual workers, and can give **full security** to the forest owner for good work. This system has however its shady side, as contractors sometimes defraud their men.

The contractor is often obliged to bring his men from a distance (as in the case of Italians employed in Germany), and he then requires pecuniary advances and concessions which are not necessary under ordinary circumstances. Timber-work is largely done by contractors in the Black Forest, Alps, Hungary, Galicia, and in many extensive forest districts of the North German Plain. In the Alps the contractors are frequently mayors of villages. Although, strictly speaking, the contractor is responsible for the conduct of his men, the forest-manager does not abstain from direct supervision over them, and it is evident that the contractor must be legally bound by conditions covering all the interests of the forest owner.

In the case of extensive damage to forests by wind, insects, snow, &c., when there is an extraordinary amount of material to be converted, it is generally necessary to entrust the work to contractors. In such cases the workmen are often brought from a distance, as Italians in South Germany, &c., and it is necessary to make arrangements which the ordinary course of forest-work does not require.

(e) **Work done by Forest Settlers.**—Hitherto it has been presupposed that for ordinary fellings the necessary labour-gang could be secured within easy distance of the forest, but there are forest districts where the population is so scattered and scanty that the needful force of labour cannot be obtained in the neighbourhood; the manager is then obliged to engage labourers from a distance and settle them in a regular colony within his forest. It is evident that only in the last extremity of scarcity of local labour would a forest-manager resort to such an expensive measure as the above.

Such colonies of forest-labourers are found at Herrenwies in the Black Forest, and in other parts of Germany, also in certain districts in Hungary. The settlers must be supplied with houses, food, medical attendance, schools and churches, plots of land to be cultivated and of meadow-land for each head of a family, also litter and firewood, and even their widows and orphans must be maintained.

[Imported labourers from Chota Nagpur are largely employed in the Assam tea-gardens under conditions similar to the above, but the Indian Forest Department has hitherto been able to dispense with the necessity of resorting to such a class of labour.—Tr.]

5. *The Forest Labour-Question.*

As already stated, the position of labourers has altered greatly in the last thirty years, and instead of the former contented, industrious woodcutter, forest management has to deal with a fluctuating proletariat. The forester is called upon to improve this state of things, not only on the grounds of national economy, but also from a special forest economic point of view; although he cannot control all the factors in the question, he can to some extent assist in reorganising a physically and morally strong force of woodcutters. Some notes showing how he should proceed to gain this object are given below.

Wages should be high enough to remunerate fairly the hard forest work and the increasing dearness of living. The supposed gain to the forest owner by low wages is often converted into a loss, ten times as great, by bad workmanship, while damage is also done to the forest. The maxim of the lowest possible wage is much more objectionable in forest work than in any other industry.

It has long been admitted by experienced foresters that it is highly advantageous to fix remuneration for work done, at rates proportional to the sale-value of the outturn. Let the roughest kinds of work be well paid, but fix rates at least double the ordinary ones for valuable produce. The amount the woodcutter thus gains will secure from him an intelligent and profitable conversion of the felled trees, will excite his attention and care, increase his utility and enable him at the same time to increase his own earnings. Small rewards should also be offered to woodcutters for new tools, and other improvements.

The system of giving the work to contractors should be abandoned, whenever it is known or suspected that the contractor is making more money than is absolutely necessary out of the workmen; in such cases direct dealing with the latter should be substituted, or other means taken to protect the men from imposition.

In order to induce good woodcutters to become attached to the forest, as far as possible permanent work should be provided for them; certain works should be kept in abeyance, so that as soon as the harvest or other agricultural business is over, work may be found for the strong young woodcutters. Naturally, in such cases, the best and most trustworthy men will be most favoured. Attempts should also be made to lighten the men's work by constructing woodcutter's huts in remote felling-areas, and introducing labour-saving appliances.

Another effective incentive is to offer the men forest privileges at low rates. Such privileges are highly valued by country people, and they think nothing of the labour involved to themselves in taking advantage of them.

Within the limits allowed by Forest Protection many a privilege of little value may be bestowed, which is paid for tenfold by the services of good woodcutters. Such are assigning small allotments of forest lands for cultivation at a low rent, during the good behaviour of the woodcutter; or of building-timber, at cheap rates, for the construction of new woodcutter's houses, or repairs of old ones.

Appointments, when vacancies arise, of useful woodcutters who have served long in the forest, as forest-guards, fire-watchers, road-guards, foremen, &c., can be only rarely given, but may be mentioned with the other means of attracting good men to the forest. The frequently indifferent pay of forest-guards, and in Germany, the preference given to old soldiers for these posts, often render the above impracticable.

In many forest districts friendly societies are established to which every woodcutter is obliged to contribute a certain percentage of his wages, and the forest owner also contributes proportionally. From these deposits allowances are made in cases of sickness or accident, and usually also to old woodcutters' widows and orphans. If these societies are to be real incentives to a steady labour-force, they must dispose of sufficient capital and offer real and sufficient help in times of need. Several of these funds are very substantial concerns; as at Clausthal in Hannover, in the Sihlwald belonging to the town of Zurich, and other localities. In some places these undertakings are of doubtful efficacy. There is now a general imperial fund for the whole of Germany to provide insurance against accident, and pensions in old age for workmen of all classes, and from this fund the best results may be expected.

SECTION II.—WOODCUTTERS' IMPLEMENTS.

Although custom, experience, and skill may to a certain extent supply the want of good implements, it cannot be denied that, in every industry, not only more but better work can be done with good tools than with bad ones. This must necessarily be the case in forestry, and the more so, the less skilful and experienced are the woodcutters who are employed. The supply of good implements is, therefore, an important object for the forest manager which he must always keep in view.

Woodcutters' implements are classified according as they are used for hewing, sawing, splitting or grubbing-up the wood.

1. *Hewing Implements.*

Hewing implements include **felling-axes, trimming-axes** and the **billhook.** The two former are heavier than the last, and are used with both hands on large timber, whilst the latter is used with only one hand, for cutting saplings and brushwood. The two kinds of axes differ, in that the former is symmetrically sharpened on both sides of the edge, and is used for converting wood in the rough; whilst the trimming-axe is used for shaping the wood, and has an unsymmetrical edge, flat on one side and sloping on the other.

Axe-heads of both kinds are made out of oblong pieces of iron which are beaten thin at the ends, and then bent to form an eye for the handle. In order to give the axe a sharp edge, a wedge-shaped piece of steel is placed between the thin iron ends, and they are then welded together, or in the trimming-axe a steel plate is welded to the side which remains flat.

The **felling-axe** is the handiest of all woodcutters' tools, and in cases of necessity, however improperly, it may be used as a substitute for almost any other tool. It consists of the **axe-head** and **handle,** the latter made of tough split pieces of ash, hornbeam, beech, robinia or service-tree; the hole in the axe-head into which the handle fits is termed the **eye,** and usually widens-out on the side opposite that where the handle is inserted, to allow of a wedge being driven in to hold the handle firmly in its place.

The part of the axe away from its edge, including the eye, is termed the **back,** and may be curved or flat, and in the latter case is often of steel. The cutting part is termed the **blade,** which may also be either straight or curved.

The characteristics of a good axe are that the edge shall be sharp, and the steel of which it is composed possess the proper degree of tempering; so that when used, on the one hand, it may retain its cutting-edge without the latter becoming bent, and on the other, the edge may not be too hard, and break. As regards shape, the axe should form a tapering wedge with smooth sides. In order to reduce friction as much as possible, the sides of the axe should be slightly convex, or there should be a slight projection in the middle of the blade. The weight of an axe, its size and relative dimensions depend on whether it is to be used for hard and heavy, or soft, light wood; in the former case, a finer but less highly tempered edge is required, and the axe should be lighter and thinner than one used for softwoods, which in all parts, and especially in the back, is thicker and broader than the former, acting more like a wedge.

In no case, however, should the axe be too large or heavy, as it fatigues the woodcutter, and does not work so economically as a lighter implement.

The **axe-handle** is sometimes straight and sometimes curved, sometimes parallel to the edge and sometimes bending from or towards it. It is difficult to decide which shape is most advantageous, and it is often made so as to taper away from the end, and thus afford a better hold.

FIG. 50.

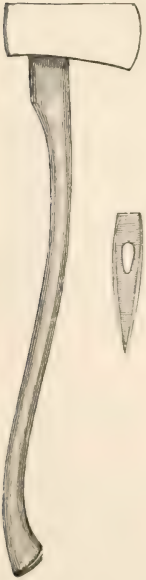


Fig. 50 shows the shape of the Kenebeck American axe, the edge of which is made of compressed steel and lasts almost indefinitely. It is said to tire the woodcutter less than any other axe, and can be readily used to cut horizontally. It is made in two sizes, weighing respectively $5\frac{1}{2}$ and 7 lbs., including the handle, and costs from 15 to 20 shillings a dozen. The handles are usually $2\frac{1}{2}$ feet long, a longer one being inconvenient, though they are sometimes used up to $3\frac{1}{4}$ feet in the Spessart and eastern part of the Black Forest. The use of these axes is spreading widely throughout Germany.

Three kinds of axes may be distinguished, viz.: the felling-axe, the lopping-axe, and the axe for cleaving or splitting wood.

(a) **Felling- and Lopping-Axes.**—The felling axe is used for felling trees, chiefly large ones which offer considerable resistance to felling, whilst the lopping-axe is mainly used for lopping branches from felled coniferous trees. The former may be of much slighter make than the latter, which meets with greater shocks; it is especially lighter in the back which is often rounded-off, whilst the lopping-axe contains more

Fig. 51.

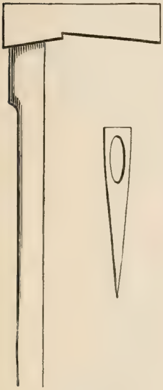


Fig. 52.

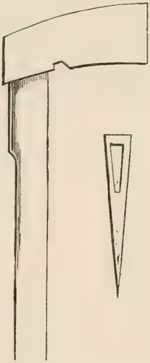
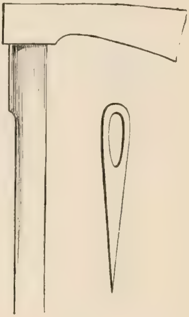


Fig. 53.



metal, and is usually flat and steeled at the back. The head of a felling-axe rarely weighs more than 3 to 3½ lbs., whilst the

Fig. 54.

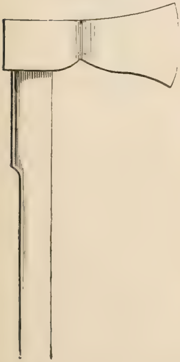


Fig. 55.

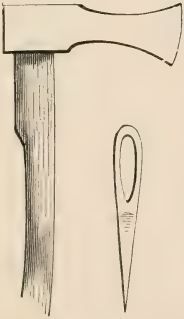
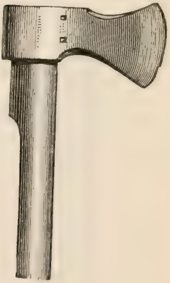


Fig. 56.



lopping-axe may be about 20 per cent. heavier. It is quite exceptional for woodcutters to have both these axes, and the lopping-axe is not required in broad-leaved forests. It is, however, a sign of a good workman to possess more than the absolutely indispensable tools.

Fig. 57.

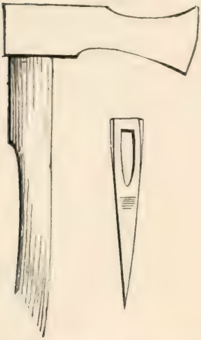


Fig. 58.

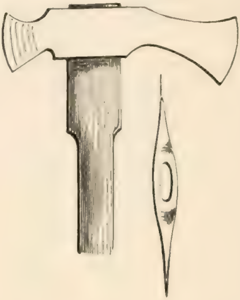


Fig. 59.

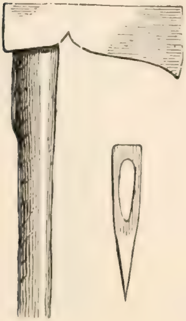
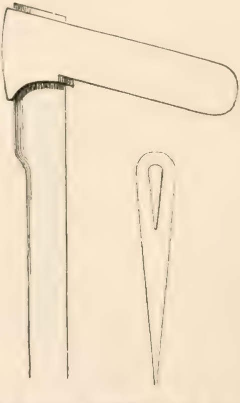


Fig. 60.



The Saxon axe (fig. 51) is quite straight-bladed from back to edge, and forms a complete wedge; the faces are slightly curved outwards, the handle is straight, and 0·75 meter (29 inches) long. The Harz axe (fig. 52) is shorter, broader, and the faces hardly curved at all. The Bohemian axe (fig. 53), also used in Moravia and Silesia, resembles the Saxon axe, but is bent downwards. The Carpathian axe (fig. 54) is broader than those already described. The axe used in the Bavarian Alps (fig. 55) is a light axe with a rounded back; the Black Forest axe (fig. 56) resembles it, but is shorter, broader, and heavier, and owing to the large timber common in the Black Forest, the handle is generally one meter (39 inches) long.

The lopping-axe used in the Bavarian Alps (fig. 57) is similar to the felling-axe, but is stouter and flat in the back, and heavier.

In the same region the double-axe (fig. 58) is used, which has a smaller head for small wood; it only weighs 1·40 kilograms, (3 pounds). The Thuringian axe (fig. 59) somewhat resembles the Saxon axe. The characteristic shape of the Norwegian axe may be seen from fig. 60; it is considered a very workmanlike instrument.

Fig. 61.

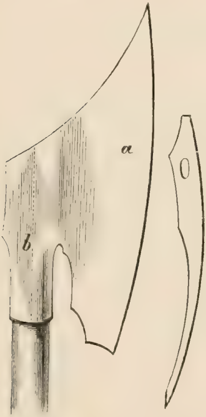
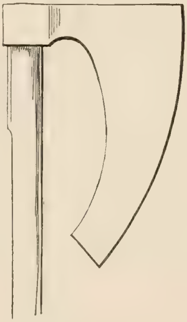


Fig. 62.



The main difference between the American axe and the various European axes consists in the devices for preventing its jamming and sticking in the cut. The faces of an axe are either provided along their middle line with a prominent ridge, or as in the Pennsylvanian axe (fig. 50), are strongly curved outwards. The blade of the latter is formed of compressed steel, hardly wears at all, and works well. By general consent this axe is considered to save labour and tire the men less than many German axes, owing to its convenient handle and freedom from sticking. [This axe is not, however, adapted for hard, tropical wood, for which the use of a narrower and lighter axe is advisable.—TR.]

(b) **Trimming-Axes.**—The trimming-axe is used by woodcutters for trimming-off side-pieces of balks, and by the carpenter in preparing timber for building and other purposes. In Germany it is usually of the shape given in fig. 61, having only one edge, and the blade being curved inwards to allow sufficient play for the hand of the operator. The handle is short, usually $1\frac{1}{2}$ to $1\frac{3}{4}$ feet, and the workman uses it sideways from the side of the log he is trimming. Another shape (fig. 62) is in use in the Black Forest, being more convenient to use on rocky and difficult ground than the former.

[Trimming-axes in India are generally symmetrically shaped, but much larger and heavier than ordinary axes, weighing up to 8 lbs. and more. The workman stands on the top of the log and trims-off side-pieces by swinging the axe vertically and merely allowing its own weight to act. The handles for these trimming-axes are $3\frac{1}{2}$ to $4\frac{1}{2}$ feet long, so as to give sufficient momentum.—TR.]

(c) **The Bill-hook.**—Bill-hooks may be of various shapes, and are chiefly used for cutting coppice or fascines, and in lopping branches from trees. Fig. 63 shows the common German bill-hook, the backward turn of the blade at its top being useful in

FIG. 63.

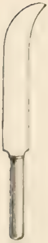


FIG. 64.

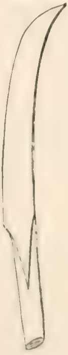


FIG. 65.

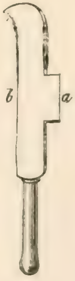
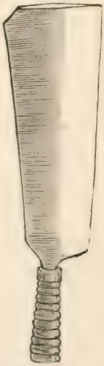


FIG. 66.



pulling out the ends of withes while tying faggots. The English fascine-knife (fig. 64) is 21 inches long and very serviceable in cutting fascines. Fig. 65 represents a very serviceable bill-hook; it is half an inch thick at the back, and has a cutting edge at *a* for cutting through branches placed on a piece of wood, as well as its ordinary cutting-edge *b*. Courval has invented a pruning bill-hook (fig. 66) which is 16 inches long and weighs about 3½ pounds; it is made thickest along its axis in order to add weight to its cuts. According to Courval all kinds of pruning, even of large boughs, may be effected with this instrument.

2. *Saws.*

(a) **General Account.**—Saws are used by woodcutters for felling trees and reducing the length of logs and branches, at right angles to their axis. A saw may be much more economically used for such a purpose than an axe, which wastes much of the wood. Under certain circumstances, and on difficult ground, the work may however be more expeditiously done with an axe. The amount of time used in sawing may vary from 20 per cent. to 40 and 50 per cent. of the whole time spent by woodcutters on the felling-area.

Forest saws were formerly rolled out of wrought iron, and the rolled blade was then hammered cold to make it hard and elastic. At present, saws are made of cast steel, and work more easily than the older implements. Owing to the superior toughness of the steel they retain their edge and set better, and owing to their smooth sides, they cause much less friction in use than the iron saws.

Saws have to overcome not only the resistance of the wood, but also the friction of their sides against the rough surface of the wood which is being sawn. Their teeth chiefly act by tearing the wood-fibres asunder, and so much the more, the more porous the wood and the longer and tougher the wood-fibres; this is therefore especially the case with soft, broad-leaved and coniferous woods. In the case of hard, broad-leaved woods, this tearing action is partly superseded by a cutting action. The more a saw tears the fibres apart the greater the amount of sawdust, which is therefore most abundant in the case of soft-woods.

(b) **Mode of Construction of Saws.**—Saws are constructed differently according to the uses for which they are intended; they vary in **shape, length, weight,** and **shape of teeth.**

They may be used either for large or small timber. In the former case they cut both ways, and are worked by two men, and termed **two-handed saws.** In the latter case they only cut one way and are **one-handed**: such saws rarely exceed 1½ to 2½ feet in length, whilst the two-handed saws may be 3½ to 6½ feet long, their length being determined by the diameter of the piece to be sawn, and the distance through which the arm moves. The weight of a saw also depends on its length.

The construction of the teeth of saws varies considerably. Each tooth may be either symmetrical or unsymmetrical, and vary in depth, thickness and distance from one another, each of which points affects the working of the saw.

FIG. 67.

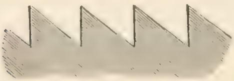
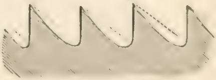


FIG. 68.



As regards the shape of the teeth, a distinction must be made between those cutting one or both ways. In the former case they are usually shaped as in fig. 67, that of a right angled triangle, the shorter side of the triangle or face of the tooth being at right angles, or nearly so, to the line of their insertion on the saw. In English saws the hypothenuse, or back of the teeth, is cut-out in a curve (fig. 68). Such teeth are only used in the case of one-handed saws, or in pit-saws used by woodcutters for sawing timber longitudinally.

FIG. 69.

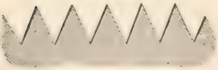


FIG. 70.

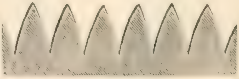


FIG. 71.

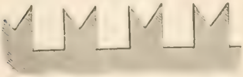
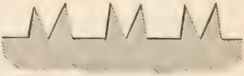


FIG. 72.



Forest saws which cut both ways require teeth of a different shape. They are always symmetrical, and usually bounded by straight lines, as in fig. 69, by curved ones, as in fig. 70, or are so-called M teeth, figs. 71 and 72, which cut both ways.

American saws have teeth as shown in figs. 73 and 74.

Space must be allowed between the teeth for the escape of the sawdust, which requires six times the space of the wood from which it is taken. This is provided by giving the teeth a much greater depth at *a b* (fig. 75) than their cutting edge *a c*, and by leaving a larger space between the teeth than their own area. In old-fashioned saws this was provided for by breaking-off the tops of some of the teeth at regular intervals, as in fig. 76, but such imperfect teeth are not found in modern saws. The triangular teeth between the combined M teeth of American saws may be considered as planing-teeth for removing splinters of wood, as they are not set like the other teeth.

FIG. 73.

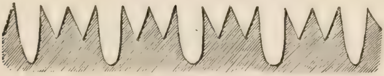


FIG. 74.

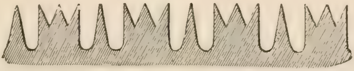


FIG. 75.

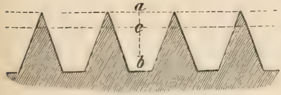
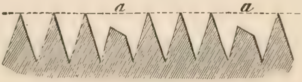


FIG. 76.



(c) **Shape of Saws.**—Various kinds of saws have come into use in different countries, of which the following are the most serviceable :—

i. *Two-handed Saws.*

The two-handed or forest saws comprise the straight, bow, and curved cross-cut saws.

The **straight cross-cut saw** is 4½ to 5 feet long, with a breadth of blade of 4½ to 5¾ inches. The handles are placed at right angles to the cutting edge of the saw, which consists of triangular teeth, with some shortened ones, and the blade is slightly convex. Such saws are used in broad-leaved forests, where there is much large timber, as in the Spessart and Rhine Valley. American saws, termed **Nonpareil saws** (figs. 77 and 78), from Disston & Sons, Philadelphia, are now largely used in Germany, and experience shows that their outturn in broad-leaved forests is 35 to 40 per cent. more than that of the ordinary German saws. In coniferous forests, on the other hand, they have not proved superior to the curved saw (fig. 81). The Nonpareil saw is made of the best steel, and has an ingenious contrivance for fastening and removing the handles.

FIG. 77.

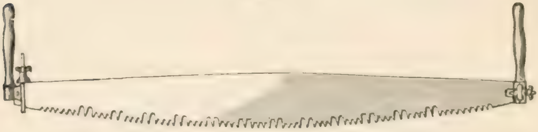


FIG. 78.

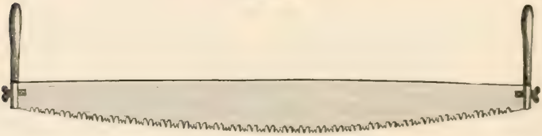
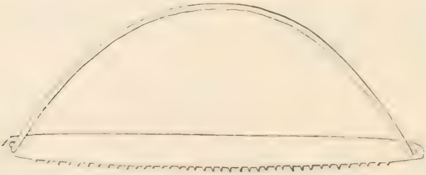
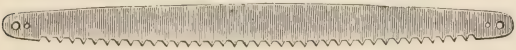


FIG. 79.



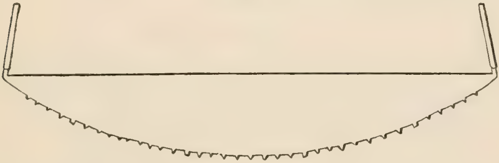
The **bow-saw** (fig. 79), which partakes of the character of a straight cross-cut saw, has a straight thin blade, which is kept rigid by means of the bow. More exertion is required to work it than the other cross-cut saws, and it is only serviceable when short. Fig. 80 represents the blade of the Bohemian bow-saw.

FIG. 80.



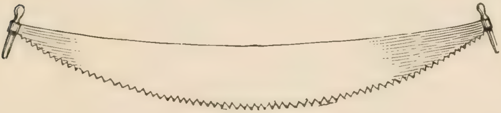
The **curved cross-cut saw** is constructed as shown in fig. 81, and the teeth are often made longer in the middle than at the two ends, where they are less in use. These curved saws vary in length and curvature, and are either straight or curved inwards at the back; they are the best cross-cut saws for coniferous wood.

FIG. 81.



The Thuringian, or Saxon saw (fig. 82) may be taken as the type of a saw in which not only the edge, but also the back of the blade, is curved. It is a very light and short saw, but is strong and turns-out good work. It is not suitable for very broad cuts, as when made long it is not stiff enough. In spite of this defect, it has, however, recently been introduced into several districts in the Black Forest.

FIG. 82.



An important adjunct to all saws are the **handles** and the arrangements for fixing them to the blade. In the older saws, the blade terminates at each end with spikes, which are driven into the wooden handles. American saws have, however, a better device, the blade not being provided with spikes, but the handles fixed to it by means of screws and nuts, the former passing through holes in the blade, as shown in fig. 83. This allows the handles to be removed readily, and the blade withdrawn from the cut; the blade can even turn on the handle, as shown in fig. 84.

Fig. 83.

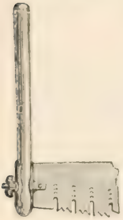
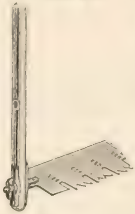


Fig. 84.



ii. *One-handed Saws.*

One-handed saws are chiefly used for removing branches and for pruning: pruning-saws have been described in Manual of Forestry, Vol. II., p. 205.

Fig. 85.

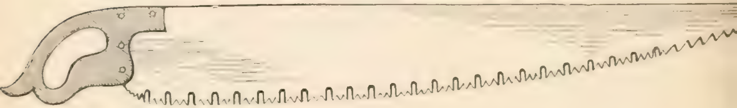
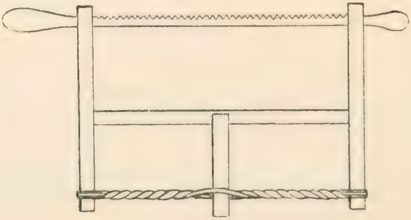


Fig. 85 represents an American saw specially made by Disston & Sons, Philadelphia, for forest work. It is used for cutting logs into lengths, and is very serviceable. It is constructed in lengths of $3\frac{2}{3}$, 4, $4\frac{1}{2}$, 5, $5\frac{1}{2}$, and 6 feet, and costs 8s. to 10s.

Fig. 86. (After Fernandez.)

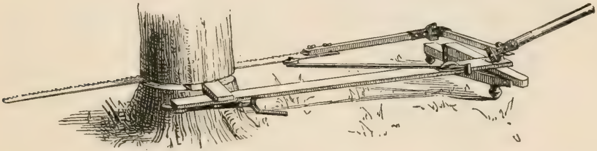


Saws used for cutting-up poles from thinnings or coppice resemble the well-known joiner's frame-saw [one used in the N.W. Himalayas being shown in fig. 86. The blade is of thin rolled steel, the teeth slightly set. In using this saw, the woodcutter improvises a sawing-block, on which he cuts up the poles into billets.—Tr.]. This mode of sawing firewood is greatly preferable to cutting poles into lengths with the axe, as it is more economical of the wood, and, after a little experience, is more labour-saving than the latter method.

iii. *Machine-saws.*

Attempts have often been made to fell trees by machine-saws, driven by steam or hand power. Ransome's steam-saw, as shown in fig. 87, is the best known in Germany. The use of these saws has not hitherto proved effective in European forests. In North America, where trees are either felled in the open, or wholesale in forests, without any care of the undergrowth, they may be serviceable: but even there the axe is the chief implement used by the wood-cutter.

Fig. 87.



(d) Mode of Using Forest Saws.

This depends on the material of which the saw is composed, its shape, dimensions, curvature, weight, shape of teeth, amount of set or extent to which the teeth are bent to either side of the plane of the blade, their degree of sharpness, and, finally, on the kind of wood to be cut and the use to be made of the wood. The strength of the workman and his degree of skill in using saws are also important factors in the question, although it is difficult to estimate them.

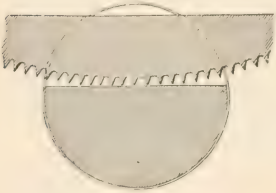
The **material** of which the saw is made is so far important, as it determines its temper and how long it will remain sufficiently sharp and retain its set. Saws rolled out of cast steel are best in these respects.

As regards **shape**, curved saws are preferable to straight ones, especially for coniferous wood, and a radius of 5 feet gives the most suitable curvature for general work.

For practised sawyers, working with a curved saw is less fatiguing, and the motion corresponds better with the movement of the arms than in using straight saws; the sawyer can also work in a more upright and less cramped position in the former case.

With a curved saw there is also more room for the sawdust and the latter is less hindering to the work, owing to the curvature of the saw (fig. 88). It must, however, be admitted that the use of curved saws requires more skilled and experienced sawyers than that of the straight saw, for the curved saw is more liable to stick when the blade is not always pushed in the same plane, a difficult thing to do at first. The chief rule is to guide the saw lightly, and use no unnecessary force.

FIG. 88.



In the case, therefore, of unskilled sawyers, such as men only occasionally employed in sawing, it is better to restrict them to the use of straight saws. For skilful sawyers, in coniferous forests, the curved saw only should be used.

As regards the **length** of saws, there is more risk of the blade bending and **buckling** (or sticking in the wood), if the saw be too long, while very short saws tire out the sawyers, and cannot be used with large timber. Lengths from 4½ to 5 feet, with a breadth of 8½ inches without the teeth, are the most effective dimensions for a cross-cut saw.

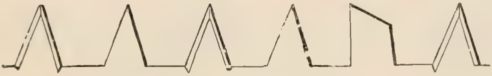
As regards the **thickness of the blade**, all saws should become gradually thicker away from the edge, but the thickness should be only sufficient to prevent too great liability to bend.

As regards **weight**, saws should not be too light, or their use becomes very fatiguing, and 5½ lbs. is the best weight.

The **construction of the teeth** is of importance, and triangular teeth are most effective; M teeth, however, give good results as shown by the "Nonpareil" saw. Triangular teeth should be ¾ inch high and ½ inch wide. The **spacing** between the teeth should be double the width of the teeth, and this suffices for coniferous as well as broad-leaved wood. Wider spacing than this, by reducing the number of teeth, impairs the efficiency of the saw. The slit made in a piece of wood by a saw is termed the **kerf.**

The teeth are sharpened with a triangular file (better with a two-faced one) and this should be done until the sides of the teeth which meet the wood are as sharp as knives. Saws which work both ways must have their teeth sharpened on both sides. As all forest saws are **set**, the stroke of the file must be always, as in fig. 89, on the inner side of the teeth.

FIG. 89.



When a saw has been properly sharpened, the tops of the teeth must not project above a general line, or the projecting ones will be broken. A good saw in constant use will require sharpening only every five or six days.

It is highly important that the teeth should retain their proper shape, whilst constant use of the saw and frequent and unskilful sharpening gradually alter it. Messrs. Dominicus & Son, of Remscheid, have introduced perforated saw-blades by which this defect may be remedied. Fig. 90 shows how this is done, and how the teeth drawn successively on the blade below the original set, can be filed down to gradually by the workmen, as the original teeth become worn-out. Fig. 91 shows how the perforations are made in a straight cross-cut saw.

FIG. 90.

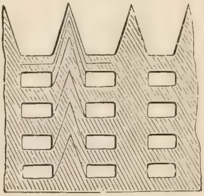
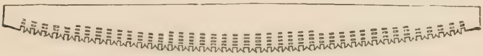


FIG. 91.



Saws are set in order that the blade may be easily drawn backwards and forwards in the wood without buckling; this is effected by forcing over the successive teeth alternately to the right and left of the axis of the blade. In order that setting may be properly effected, the metal must be sufficiently soft for the teeth to bend without breaking, but the blade must not be too soft, or the teeth will retain neither their edge nor their set.

By use, the teeth lose their sharpness and come back into their original position. The chief excellence of cast-steel saws consists in the fact that they retain their edge and set much better than old-fashioned saws. If any of the teeth are too hard they can be softened by holding them for a few seconds between a pair of red-hot pincers. For setting the teeth of saws a **key**, usually of the shape shown in fig. 92, is used, the teeth being held in one of the grooves, and then bent-over. Fig. 93 is a mechanical apparatus for setting the teeth of saws in a very regular manner. The blade *m n* (shewn in section) rests on the adjustable screw *d p*, which may be raised or lowered, and on the anvil *o o*, so that the teeth pass successively between *a a*, and are bent by the hammer *k*. The apparatus is firmly fixed to a solid basis by the spike *c*.

FIG. 92.

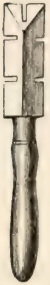
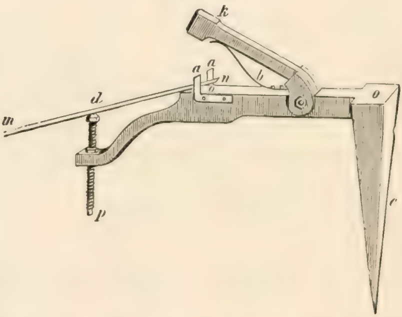


FIG. 93.



Figs. 94 and 95 represent other mechanical **saw-sets**; in both of them *a* is a bar which drives the teeth into position.

A wider set is usual with softwoods than with hardwoods, and long saws also require a wider set than short ones. The set should never be more than double the width of the blade at the base of the teeth.

Recently in America saws have been much used with permanently set teeth, their thickness being greater than the blade of the saw.

FIG. 94.

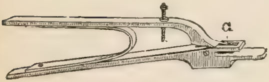
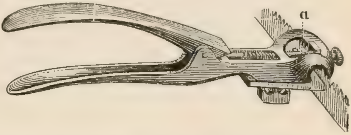
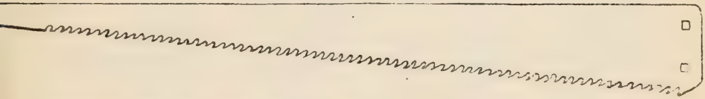


FIG. 95.



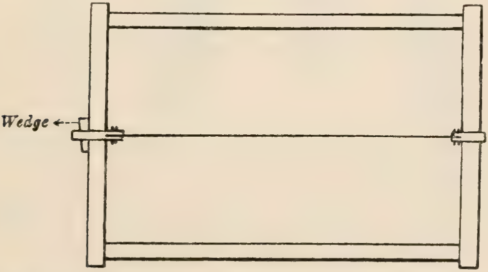
The action of sawing is furthermore affected by the resistance of the different woods: this is greater in large pieces than in smaller ones and for trees with knots than for even-grained wood; the degrees of resistance offered by woods of different species of trees to sawing have been already given (p. 37).

FIG. 96. (After Fernandez.)



The measure of the work done by a saw is the surface sawn per minute, measured in square feet; a good cast-steel saw will frequently do three times the work of inferior saws, and will thus save labour considerably.

FIG. 97. (After Fernandez.)



[**Pit-saws** (fig. 96) for longitudinal sawing are not so much used in forests as was formerly the case, owing to the fact that logs are generally removed in the round from forests and converted into planks, &c., in saw-mills. Such saws are still, however, largely used in Indian forests; also frame-saws (fig. 97) which have very thin blades and are easily transportable, the frames being made in the forest. *In Indian saws also the teeth are filed so that the cutting edge is towards the operator, and much thinner blades can be used than when the saws cut in thrust as in Europe.—Tr.]

3. *Tools for Splitting Wood.*

Besides those stave-making implements already described (p. 143 *et seq.*), the **iron or wooden wedge**, and the **cleaving-axe** are required for splitting wood.

(a) **Wedges.**—Iron wedges usually have a wooden head, which is surrounded by an iron ring to prevent it from splitting (fig. 98).

Wedges may also be entirely made of iron, but they are then driven into the wood by a **beetle** or wooden mallet, whilst the wooden-topped wedges may be driven in with the flat steel back of a splitting axe.

Fig. 98.

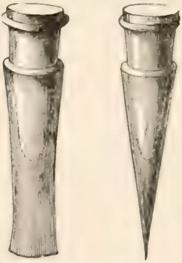


Fig. 99.

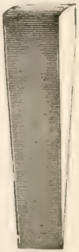
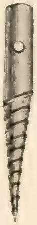


Fig. 100.



Wooden wedges (fig. 99) are prepared by the woodcutter out of tough middle-aged beech or hornbeam-wood, and are frequently surrounded at the head by an iron ring.

Iron wedges are considered more serviceable for splitting tough wood; where wooden wedges are used, a cleft must previously be made in the wood with a cleaving axe. There is, however, a risk that iron wedges may spring out of the wood, the friction against their smooth sides being less than with wooden wedges, and this not unfrequently happens with cracked or frozen wood. Sand or dry earth is placed in the cleft to prevent this, and a proper shape of the wedge renders it less likely to happen. Thus, if the sides of the wedge be flat instead of curved, or grooves $\frac{3}{4}$ inch broad and $\frac{1}{8}$ inch deep cut in them, during use the wood is pressed into these grooves and the wedge thus firmly held.

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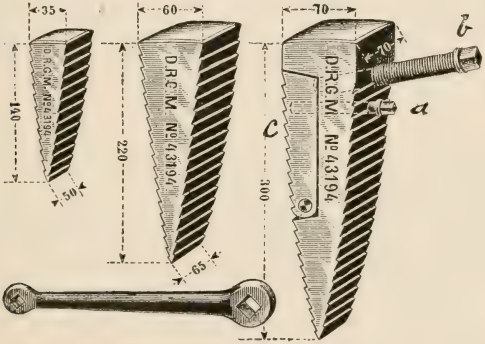
* Fernandez, Utilization of Forests, p. 86.

Quite recently a **screw wedge** (fig. 100) has been invented for use while trees are being felled, and this is held fast by the wood.

FIG. 101.



[Fig. 101 represents a toothed wedge, invented by Schnücke, which is used for forcing over a felled tree, or splitting tough roots, the wedge is driven-in up to (*a*), the bolt (*a*) then removed and (*c*) forced outwards by the screw (*b*). (Nos. on fig. are centimeters).—Tr.]

(b) **Cleaving axes.**—The cleaving-axe differs from the felling-axe by its superior weight, size and greater resemblance to a wedge. It generally weighs $4\frac{1}{2}$ to $5\frac{1}{2}$ lbs., or even up to 8 lbs. in special cases, but resembles felling axes in shape, except that its back is flat, and generally made of steel, to render it more suitable for driving wedges into wood.

Fig. 102 represents the cleaving-axe used in the Harz, it is two inches (5.5 centimeters) broad at the back, and weighs about $5\frac{1}{2}$ lbs. Fig. 103 is an axe used in Upper Bavaria and weighs about 5 lbs., its flat back is used for breaking off dead stumps from felled stems as well as for driving in wedges. Fig. 104 is the Thuringian cleaving-axe, and is very heavy. The Bohemian cleaving-axe (fig. 105) has the stoutest shape of all these axes, and may be used for splitting firewood into the smallest pieces used for stoves. The Vienna cleaving-axe (fig. 106), weighs up to 9 lbs.

Fig. 102.

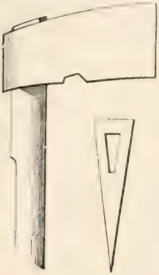


Fig. 103.

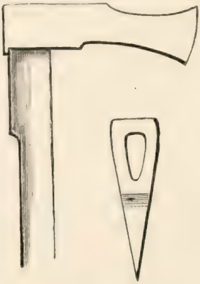


Fig. 104.

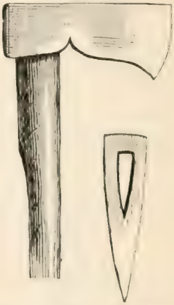


Fig. 107 represents an axe used in certain districts in Silesia, and is a good implement.

The divider (fig. 41, p. 103) has been already described as a tool used for splitting staves. Other tools used for splitting firewood into small pieces are not woodcutters' implements.

4. *Implements for Extracting and Splitting Stumps and Roots.*

Implements of a very simple nature are used in converting the parts of a tree which are above ground; those used for extracting and converting the stumps and roots are much more multifarious.

(a) **Simple Grubbing Implements.**—The simplest tools used for grubbing-out roots are the **mattock**, the **pick**, the **pick-axe** and the **grubbing-axe**. Short saws, wedges, crowbars are also used for severing, removing or splitting the stumps and roots of a tree.

The mattock (fig. 108) is about one foot long and 2 to 2½ inches broad, it is made of good steel and strongly fixed to its handle and is used for digging into the ground and severing small roots. The pick (fig. 110), which is sharply pointed, is used as well as the mattock for this purpose on stony ground, and both tools may be combined in the form of the common pick-axe (fig. 109).

The grubbing-axe serves for severing the exposed larger side-roots, and is merely a small-edged felling-axe (fig. 107A); as, however, it wears out rapidly owing to the stones, &c. with which it comes in contact, usually a worn axe no longer serviceable for felling trees is used for the purpose.

FIG. 105.

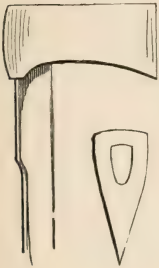


FIG. 106.

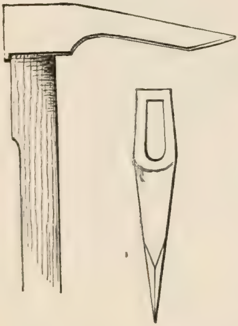
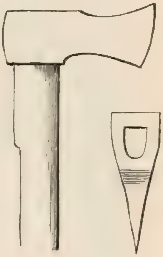


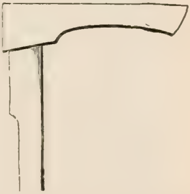
FIG. 107.



In order to separate large spreading side-roots from the stump of a tree, a saw is generally used instead of an axe, and the ordinary carpenters' frame-saw is preferred.

Tough wooden levers, the size of a cart-pole, and 6 to 10 feet long, which are cut into wedges at one end, are used for breaking up the side-roots after they have been separated from the stump. Besides these levers, wooden wedges of different sizes are used and their use will be explained further on with the operation of uprooting stumps.

FIG. 107A.



A long iron wedge fitting over a wooden handle, the end of which is surrounded by an iron ring, is also used in separating deeply situated roots.

Fig. 111 represents a hook which fits over a thin wooden pole, and a rope is fastened to it by means of which, after the hook has been attached to a branch, a tree may be pulled-over by the roots.

The hook is sometimes merely fastened to a rope, and may be attached to a branch by a man climbing the tree. This plan can be employed only in the case of tall slender stems, as climbing trees to attach the hook wastes too much time.

Fig. 109.

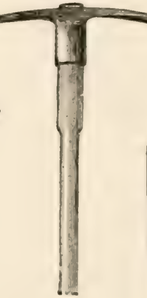


Fig. 108.

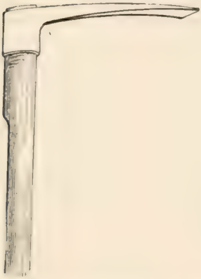
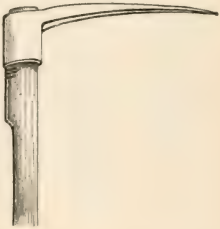
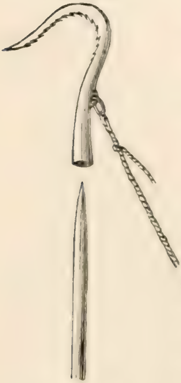


Fig. 110.



(b) **Machines for removing Stumps.**—In order to save much of the labour involved in using the tools just described for grubbing-out roots, various machines have been invented for the purpose. Of numerous modern inventions only the **Hawkeye machine**, the **forest-devil**, the **kant-iron** and **lever**, **Wohmann's machine** and the **screw-jack** will be described.

Fig. 111.



The **Hawkeye Machine** (fig. 112) consists of an iron vertical axle fixed on a firm support, moving in sockets placed above and below it, and surrounded by a drum *c*. This drum can be firmly attached to the axle, or loosened from it by means of the lever *b*. The axle with the drum attached is set in motion by a horse moving the shaft *a*, and thus a flexible steel rope 160 feet long which is attached at one end to the drum may be wound round the latter. The rope passes round the pulley *n*, which is attached to a powerful hook fixed to the stump *R* to be extracted, the other end of the rope is also attached by another hook to a support *C*. The distances *A R*, *R C*, as shown in the figure should be relatively increased from 6 to 10 fold.

The Hawkeye machine is extremely powerful, and not only pulls out the stump, but also the long lateral roots attached to it. It is specially useful in clearing wood-land for agriculture, and may also be used for uprooting trees. In one day, with a horse and two men, 20 to 25 large stumps may be extracted at a cost of about 15 shillings. The machine may be purchased from Brandt at Munich, agent to the firm of James Milne and Son, Manticello, U. S.

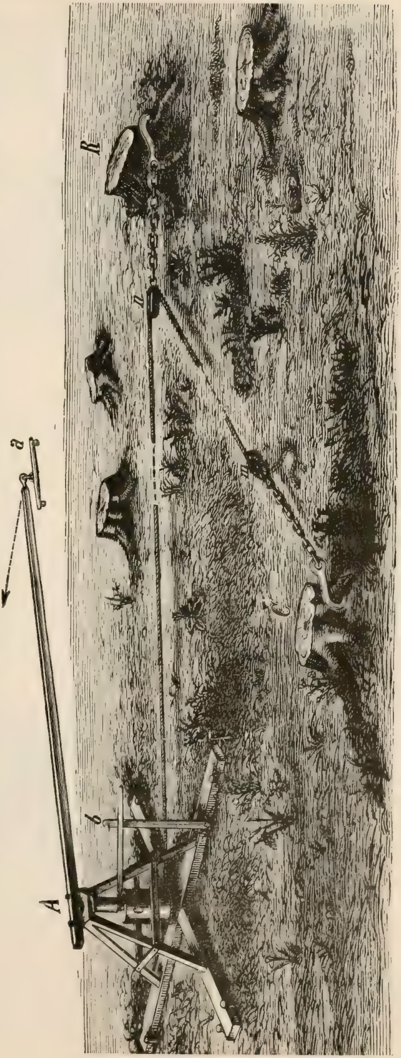


FIG 112.

Another root-extractor is termed the **forest-devil**, and has been in use for a long time in Switzerland and also in Germany. It consists, as shown in (fig. 113), of two strong iron chains between which a wooden lever works. One end of the chain *A* is fastened to a neighbouring strong root, stump, or tree, and the other is attached to the lever, at its fulcrum *o*. The second chain *B* is placed round the tree or stumps to be extracted, which must naturally offer less resistance than that to which *A* is fastened; it is connected with the lever alternately by means of two short chains each terminating in a hook. By then moving the lever backwards and forwards and hooking first one and then the other of these chains into links of *B*, the tree or stump may extracted.

FIG. 113.

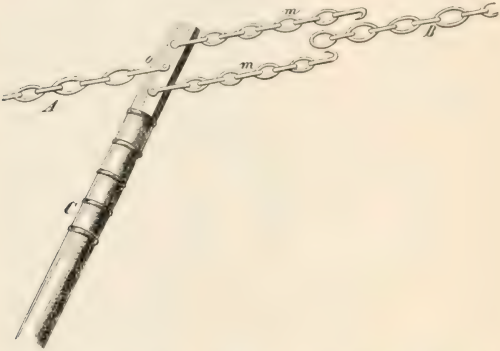
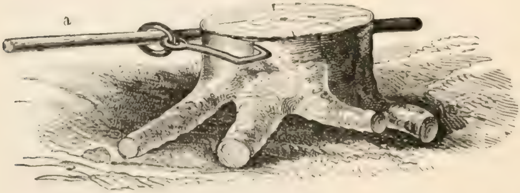


FIG. 114.

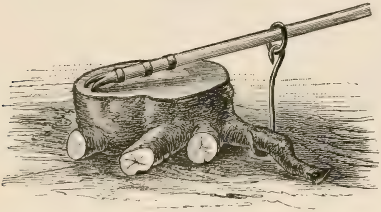


A strong rope may be used instead of most of the length of

B, as long as there are sufficient links in it for working the lever.

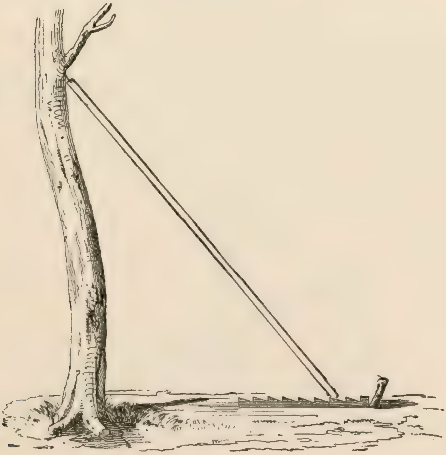
Another method for extracting stumps is shown in figs. **114**, **115**, by means of a lever with a sliding ring and kant-iron or hook.

FIG. 115.



Wohmann's machine for pushing down trees is shown in fig. 116.

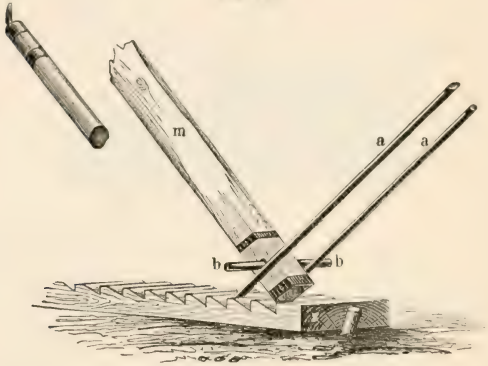
FIG. 116



It consists of a long coniferous pole, with an iron spike at one end, and at the other, it is bored, as shown in fig. **117**, to admit a short iron bolt.

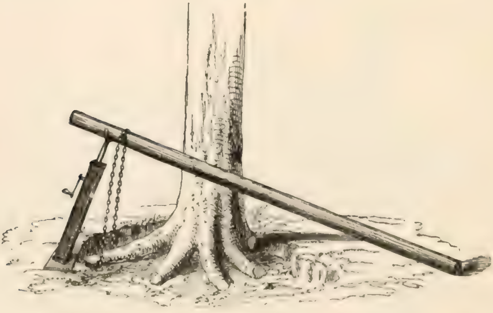
This pole is fixed into the tree and then the other end is placed on a grooved board and lifted from groove to groove by two iron levers. In this way the tree is gradually pushed over, the action being most effective when the pole is at an angle of about 45° with the board.

FIG. 117.



The great weight, about 5 cwt., of this machine has prevented its coming into general use, but Draudt has constructed one of only half that weight, and Laubenheimer has substituted for the grooved plank an endless iron screw, on which a car supporting

FIG. 118.



the pole is moved forward by means of a winch, and he states that this gives 8 to 10 times the pressure of the original arrangement.

Ordinary **screw-jacks** (fig. 118), are also used with advantage, as in the Schwarzwald, for uprooting trees and stumps. Recently, in Württemberg, a portable windlass has been used with good results both for uprooting trees and stumps, and for dragging loads of timber up steep inclines. Provided that the cost of working it is not too great, its use is to be recommended on account of its great power and adaptability.

SECTION III.—SEASON FOR FELLING.

The proper season for felling depends on several circumstances, of which the most important are,—**the climatic conditions, available labour-force, mode of felling, technical quality of the outturn**, and **species of tree**, besides some other special points depending on particular cases.

1. *Climatic Conditions.*

These are in many regions the most important of all the circumstances which determine the season for felling ; for where the winter is severe and the fall of snow heavy and lasting, so that outdoor work has to stop, as in most high mountain districts and in many localities only moderately elevated, forest work during winter may be impossible. In case fellings cannot be carried on during winter, transport by means of sledges, which is facilitated by the snow, may be effected. In high mountain regions, therefore, transport of timber and firewood is the chief occupation during winter. In plains and low hills the severity of winter rarely interferes with the work of felling, which is generally continued uninterruptedly during this season.

2. *Available Labour-Force.*

In most districts labour is more abundant in winter than in summer, when agriculture offers constant employment. In case, therefore, other stronger reasons to the contrary do not exist, forest management is interested in utilizing the otherwise unemployed winter labour-force.

This is the more urgent, the more agriculture is the chief employment of the local population, which is not the case in extensive forest tracts, where the men work nearly the whole year in the forest, and do not care for other work, whilst the women and children cultivate the small agricultural area. If there are plenty of transport animals in such a country, carting is done chiefly during the open season, or whenever the roads are most passable (which in clay soils with unmetalled roads may be during frost); the timber may also be floated during the open season. In industrial countries, where factories abound, there is generally a scarcity of forest labour throughout the year, and especially in summer.

3. *Mode of Felling.*

On sylvicultural grounds, as regards those modes of felling which are not concerned with reproduction, such as clear-cutting, the season is of only slight importance; it is more important, as in thinnings, when tending the woods is in question, as well as removal of some of the trees.

Natural regeneration fellings, especially in broad-leaved woods, must be effected when the fall and transport of the trees will do the least amount of harm to the shelter-wood and young growth, and that is in winter, whenever the ground is covered with snow.

Clear-cuttings may be effected at any season of the year, unless they are to be immediately followed by sowing or planting.

Thinnings in young woods are best done whilst the trees are in full foliage, and the best season for them is autumn. When, however, quickly-grown, slender poles in a densely-grown wood are thinned late in the autumn, in exposed localities subject to breakage by snow or rime, they are very liable to be bent or broken; whilst, if the thinning be executed in spring or summer, they have time to become stronger and often to escape the danger. Whenever **injured trees**, broken by the wind or snow, or killed by insects, have to be felled, this is usually done in summer for broad-leaved trees; but in coniferous woods the injured trees should be felled as soon after the damage as possible.

For **pruning** the branches of broad-leaved trees, provided the wounds are tarred, autumn and early winter are the best seasons, but in the case of resinous conifers, pruning may be done at any season.

[Where tarring is not effected, February is the best month for pruning.—Tr.]

Regeneration-fellings among broad-leaved trees, and especially secondary fellings on steep slopes, are best effected over a deep layer of snow, in order to protect the young growth from damage during the removal of the timber. During summer, when vegetation is in full activity and tender shoots are so easily injured, broad-leaved forests should be left alone; and the same rule should also be applied to coniferous woods with natural regeneration, unless the winter is too severe for fellings; but, even then, the period between the sprouting of the young shoots and their full development should be one of repose.

For **coppice**, late winter is the best felling season, for if the wood is felled early in the winter, it frequently happens that the stools are killed by the severe cold. Whenever, for certain reasons, autumn or winter fellings are necessary, the stools should be cut as deep as possible in the ground. Cutting coppice during the period of vegetation gives rise to weakly coppice-shoots.

Wherever stumps are to be extracted, this is generally done during summer, and naturally cannot be done at all when the ground is frozen.

4. *Quality of Outturn.*

As regards the influence of the season of felling on the quality of the outturn, the question has already been discussed (p. 82), and it has been determined that for firewood the season has hardly any influence, provided the wood be thoroughly dried, but that the qualities of timber are greatly influenced by the season of felling and the subsequent treatment of the felled material.

As a rule, broad-leaved trees should be felled only in winter, and the same rule is desirable for coniferous wood, unless it can be removed from the felling-area and sawn-up immediately after it has been felled; winter-felling is also best in the case of old and imperfectly sound trees.

Whenever climate is against winter-felling, the most valuable trees should be felled late in the autumn; this is the more essential, the greater delay there is likely to occur between the felling and the sawing up of the timber, or the removal of it to sheltered, airy timber-yards.

5. *Species of Tree.*

Conifers, and especially the spruce, are most liable to be worm-eaten; and to protect them, the bark should, as soon as possible, be peeled from off the felled trees. Thorough barking is possible only in summer, whilst in autumn or winter the bark can only be partially removed; this, however, is quite sufficient to protect the wood from insects and to allow of its thoroughly drying. If the trees are felled in autumn and partially peeled, the fact that the bark is left as a thin coating prevents the wood from cracking.

6. *Special Application of the Material from Felling-Areas.*

Exceptions are made when the material from the fellings is required for special purposes.

Thus, for bent-wood furniture, and for certain impregnation processes, and in the case of cloven wood, the trees should be felled in summer. If bark is to be used for tanning, the trees must be felled in the spring. Wood used for wells and water-pipes is also sometimes felled during spring.

7. *Modes of Transport.*

As regards transport, it is found that wood felled in summer is lighter to carry, and floats better than winter-felled wood; hence less firewood sinks, and the timber-rafts are less heavily laden, owing to the wood being much more thoroughly dried than when felled in winter.

8. *Demands of Timber-Market.*

The possibility of getting a good price for timber often depends on the time fixed for the timber-sales, and the latter depends on the time the trees are felled. Where other considerations are not predominant, the felling period should be so arranged that the material may come to market at the season when the best prices are offered.

Thus, hop-poles and bean-sticks are best felled in the early winter, so that they may be sold before the spring. Timber merchants under contract to supply certain goods, such as railway-sleepers, &c., are bound to do so before a certain fixed date, and this circumstance will guide the forest manager in fixing the time for his fellings.

Finally, it is easy to see that certain local circumstances may affect the felling period, such as accessibility of the ground, &c. Sometimes in alder-woods on swampy ground, the timber can only be removed when the ground is frozen. Where regular inundations occur during spring, it may be necessary to fell in summer.

[In N. India during the monsoon (July–September) all fellings are stopped in the plains' districts, and the month of October is so malarious in some sub-Himalayan forests, that woodmen could only frequent them at that period at the risk of their lives.—Tr.]

9. *Summary.*

To summarise the above: it may be laid-down that in localities with a mild climate, winter should be considered the normal season for felling; in high mountain-regions with heavy snowfall and extensive coniferous forests, summer- or rather autumn-fellings are generally necessary.

Winter-felling occurs from the end of October till the end of March; it is the most natural period for the work, as the forest is at rest from vegetation, whilst the outturn is likely to be more durable and of better quality than summer-felled wood. Fellings cannot, however, be continued uninterruptedly during winter in the lowlands; deep snow may prevent the men from felling the trees sufficiently low down, and hard frost may render it difficult to split the wood and injure the coppice-stools, whilst much firewood is burned during the long, cold evenings by the wood-cutters.

As regards the distribution of different fellings during the winter months, seeding and secondary fellings in broadleaved woods are usually commenced immediately after the leaves have fallen, and the felling-area should be cleared before the seeds germinate, or the buds of the young growth sprout; this is often the case in March with beech. Wherever the logs are to be slipped down steep inclines, and the workmen are not particularly trustworthy as regards protection of undergrowth, these fellings may be delayed till there has been a heavy fall of snow, or they should be effected in open weather, and not during frosts.

Clear-cuttings in coniferous forests are not undertaken until all the more urgent natural regeneration-fellings have been undertaken or are nearly concluded. Then thinnings or preparatory fellings may also be carried out in old woods. Thinnings in young woods and cleanings end the series, and are often done during the autumn.

It is better to begin winter-fellings with the large trees, and on felling-areas where these are numerous, and then to proceed with the conversion of firewood. Supervision is thus facilitated, and the heavy pieces are soonest removed from the forest.

In very large forest ranges richly stocked with old wood, the manager may be satisfied if the more important fellings are done during winter, and in summer all wood worked-out which is broken by snow or wind or dead from other causes. Wherever summer-felling prevails, all the labour-force is engaged in transport during the winter.

Summer-fellings begin, according to the locality, in April or May, as soon as snow and frost permit and the labour-force which has been occupied in transport during winter is available. Where the men are engaged during summer in charcoal-making or other employments, or where with a view to the quality of the wood, it is desirable not to fell the trees in full sap (July—August), these fellings should be suspended till September, and continued as long as the weather is favourable. The work is then so arranged that reproduction-fellings and fellings of valuable timber-trees are effected as early as possible, so that they may be finished before the buds shoot. The underwood is then highly elastic and suffers least from abrasion, whilst the logs can be barked and preserve their esteemed white colour.

Later-on, after the season of vegetation has commenced, firewood trees and other inferior sorts are felled, and the felling of whatever valuable trees were not felled before their sprouting, will then be deferred till September.

In high mountain-regions where felling, conversion and transport cannot be completed during one summer, it is usual during the first summer and autumn to fell the trees, bark all the logs, and prepare them for transport, and remove them to the depots after snow has fallen. The firewood is then prepared in the second summer, carried down on sledges to the depots during winter, and floated away in the spring. It is rare that more than two years are allowed for clearing a felling-area; in such cases the logs which have been so long lying in the forest rarely arrive at their destination in a perfectly sound condition, and yield only inferior material.

Whenever great damage has been done by storms or snow, the first measure is to clear the fallen wood from the roads and ridges, and then all trees which have fallen over young growth or poles are removed. After these cases have been attended to, woods where extensive breakage has occurred are cleared, and then places where single trees have fallen or have been rendered insecure, all injured trees which may serve as breeding-places for insects being felled.

SECTION IV.—METHODS OF FELLING.

1. *General Account.*

As a rule, work is begun in as many felling-areas as there are gangs of woodcutters available, and care is taken to sub-divide equally all immediately impending work in so far as the natural sylvicultural sequence of the different modes of felling does not interfere with such a plan. This latter consideration is especially important in secondary and selection fellings, and in thinnings of mixed woods, which require great care on the part of the woodcutters and the constant supervision of the forest staff.

Not unfrequently one gang may be distributed over several felling-areas, and when it is important to expedite the work owing to impending hard weather or heavy snow, several gangs may be employed in one felling-area.

In order to divide the work fairly amongst the men, the felling-areas, which have been previously marked-out on the ground, may be divided into as many equal subdivisions as there are parties in a gang; or in the case of secondary or selection fellings, or extraction of large trees over underwood, a certain number of trees may be allotted to each party of woodcutters.

Each subdivision of the work is numbered and termed a lot, and the parties draw numbers to decide on which lot they will work. In forming the lots great care should be taken that the distance over which the material has to be moved is nearly the same in each case, so that all the parties may have about the same amount of work to do.

The lots should not be too small, and especially not too narrow, or the men would be subject to constant interruption by those of an adjoining lot. On mountain-slopes they are therefore placed side by side, running downhill. In such places it is often advisable to leave lots between two parties unallotted, on account of danger of accident from falling trees, &c., work on these intermediate lots being subsequently undertaken.

Some lots may also be reserved to be given afterwards to the most industrious men, whom the manager wishes to keep constantly employed in the forest. It is advisable to allow the woodcutters themselves to distribute the lots amongst the parties, so as to avoid all charges of partiality against the forest manager.

As regards the actual felling, it is clear that sylvicultural rules and those for giving the best outturn must be followed by the men, so that the felling may be conducted with a care for the trees and young plants which are allowed to remain on the area, that the felled material is not wasted, and labour is economised as much as possible.

Here will be considered the **different methods of felling trees**, their **relative advantages and disadvantages**, and the **general rules** to be observed in the conduct of fellings.

2. *The different Modes of Felling.*

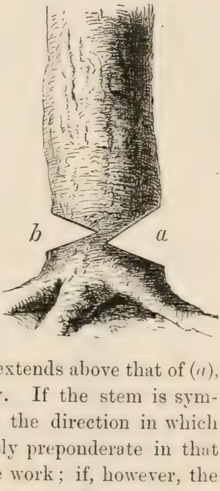
The different modes of felling depend on the implements used; they may be further distinguished as:—utilization of the stem, and of the roots and stump of a tree.

(a) **Utilization of the Stem.**

i. *Felling with the Axe.*

The stem to be felled should be cut with the felling-axe in two places on opposite sides of its base (fig. 119), and as near the ground as possible. The wedge-shaped notches thus cut in the tree become larger and approach nearer the axis of the tree until the latter falls. These notches should be kept as small as is consistent with the easy admission of the axe, and should have smooth sides. As a rule, the height of the opening measured on the bark of the tree should not exceed its depth.

FIG. 119.



In order to throw the stem in any desired direction, the two notches should lie opposite to one another in that direction, and the former one (*a*), (fig. 119) on the side where the tree is to fall, should penetrate beyond the axis of the tree as deeply and horizontally as possible. The other notch (*b*) should be begun from four to six inches higher than (*a*), according to the thickness of the stem, and cut so that its point extends above that of (*a*), or would do so if produced horizontally. If the stem is symmetrical it should be lightly pushed in the direction in which it is to fall. If its weight should slightly preponderate in that direction, that will naturally expedite the work; if, however, the weight preponderates on the other side, or towards either direction at right angles to that of the intended fall, a billet of easily-split firewood may be put in the notch (*b*), and several wedges then driven into it transversely, or between it and the edge of the notch, so as to press the stem over to the side on which it should fall.

In the case of valuable timber-trees, it is often advisable to cut them below the surface of the ground so as to save a portion of the stump as timber. In that case the notches are cut down as deeply as possible, and often the earth is dug away all round the stump of the tree. It is then often insufficient in the case of large trees to cut only two notches, but cuts are also required at the other sides, though they should never be as deep as the principal notches in the direction of the fall. Small trees may be felled by one man, trees from 10 to 12 inches in diameter by two men working together, and very large trees by four men.

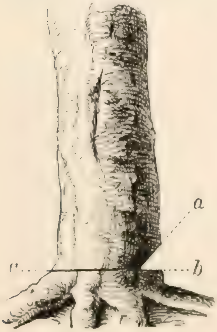
ii. *Felling with the Saw alone.*

In the case of small trees, the saw-cut is commenced on the side opposite to that of the proposed fall, and continued until the tree can be pushed-over; in the case of large trees, owing to friction, the sawing cannot, without some help, be continued beyond the axis of the tree; as soon as possible, therefore, two wedges are driven-in behind the saw, and as the sawing proceeds they are driven further and further until the tree falls.

iii. *Felling by means of Axe and Saw.*

The sawing (fig. 120) is commenced at the side (*b*) on which the tree is to fall, and continued to about $\frac{1}{4}$ or $\frac{1}{5}$th of its diameter, and a notch in direction (*a*) is made with the axe to meet this saw-cut.

FIG. 120.



The saw is then taken to the opposite side of the tree, and as soon as the cut (*c*) is deep enough wedges are inserted behind the saw, and from time to time driven further until the tree falls.

iv. *Felling with the Billhook.*

This is restricted to small poles, saplings and coppice-shoots forming a dense growth in which there is no room to use the axe. Saplings are felled with one blow of the billhook, but if a stem is too thick for this, it should be felled with two blows on opposite sides, without making a regular notch.

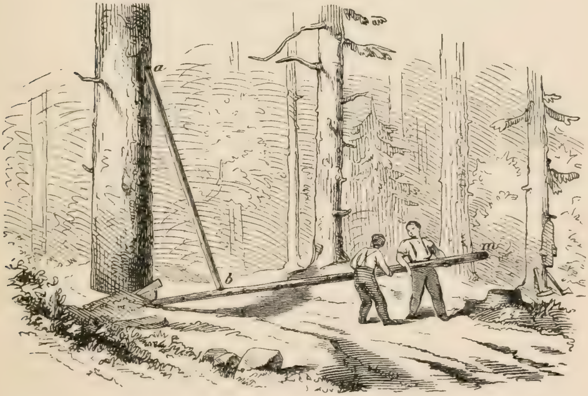
v. *Felling by Means of an Electric Current.*

A thin metallic wire brought to a white heat by an electric current may be used as a saw for felling trees, the wire being stretched in a frame the handles of which are isolated. Experiments* have thus been made on a large scale, the stems being cut so deeply with the electrified wire that they can be thrown by means of wedges. A longer experience will show whether or not this method can be applied practically to forest work.

vi. *Advantages and Disadvantages of the Different Methods.*

The characteristics of a good method of felling are, above all, that it is not **dangerous for the workmen**; that the tree is **thrown accurately in the desired direction**, the most important sylvicultural point in the felling; then, that it **wastes as little wood as possible**, and finally, that it involves **the least possible amount of labour**.

Fig. 121.



Experience has shown that felling by means of saw and axe combined, with the help of wedges, is the best of all methods, for in no other way can the tree be so accurately thrown in any desired direction, or is it less liable to splinter in falling.

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* Patent and technical bureau of Richard Bayer, Berlin.

Where the saw alone is used, several wedges may indeed be introduced, but the tree rests on one point of the circumference of the cut, and during the fall it frequently turns on its stump in a way which cannot be prevented by the use of wedges. If, however, a small notch is cut on the side of the fall, and the saw-cut opposite to this is opened-out by wedges, the stem when ready to fall rests, as shown in fig. 120, not on a point, but on a straight line perpendicular to the direction of the fall, and any turning of the stem on its stump is an extremely rare event. A very simple and safe method has been long in practice in the Schwarzwald, as shown in fig. 121; the pole *ab*, fitting into a notch in the stem at *a*, is lifted by two men by the horizontal lever *mb*, and is thus forced into the required direction. This is a simple form of Wohmann's apparatus.

The greatest **waste of wood** is involved when the axe alone is used for felling, and this not only because a considerable portion of the base of the tree is hewn into chips, which in mature trees may be 4 to 7 per cent., and in poles, 2 to 2½ per cent. of the volume of the bole; but also because the end of the log remains pointed, and it cannot be used in its full length.

Where the saw alone is used, there is least waste (about ½ per cent.), but even where both saw and axe are used the waste is small (1 to 1½ per cent.). There are, however, localities where working with the saw involves a greater loss than when the axe alone is used, and that is in steep rocky places where one is obliged to leave a high stump in order to work the saw at all.

The loss of bark in conversion is 4 per cent. of the prepared bole for the beech, and other smooth-barked trees, 7 per cent. for oaks and coarse-barked broad-leaved species, 8—11 per cent. for the Scotch pine, spruce, and silver-fir, 15—18 per cent. for the larch and black pine.

As regards **facility in working**, this depends on the practice and skill of the woodcutters. We should only compare the labour of men equally skilled with saw and axe, and in such cases there is very little advantage in using the axe alone.

Felling trees by means of axe and saw combined is, therefore, under ordinary circumstances the best method, and should be everywhere introduced, where custom still clings to the use of only the axe. It is only impracticable on steep rocky ground, and unsuitable in the case of very large valuable timber trees which should be felled out by the roots, and in thinnings in densely grown poles, where there is no room for sawing.

The disadvantages of the use of the saw and accompanying wedges, must not, however, be overlooked. This frequently increases heartshake, a circumstance which deserves full consideration in the case of valuable timber trees; besides this defect, very tall thin stems, when half cut through, may split in two if the wedges are carelessly used, and such a split often proceeds high up the stem. This disadvantage in the use of the saw depends, however, less on the method than on the carelessness of the workmen.

(b) **Utilization of Roots and Stumps.**

This can be effected either by **extracting the stumps of trees**, or by **uprooting the trees themselves.**

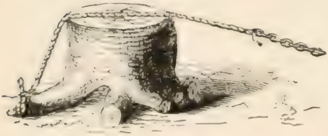
i. *Removal of Stumps.*

Stumps are utilized by means of grubbing-axes, saws, wedges, crowbars, &c., or with the help of machines. The principal part of the work is that of grubbing-out the stump, which takes 70 to 90 per cent. of the labour involved in the whole operation. The work is commenced by digging all round the stump, and exposing all the side-roots as far as they are worth extracting. All these roots are then severed close to the stump and removed, the longer ones being severed at the thinner end as well. The workmen then continue to dig round the deeper going roots, or taproot, until their upper parts are exposed and can be severed, or extracted with the stump. Another way, after the roots have been exposed by digging, is to split the stump into pieces, and extract these separately; for this purpose iron crowbars are used, or the stump may be blown-up with gunpowder, as will be described further on.

It is evident that uprooting stumps is a most laborious process, and attempts have naturally been made to lighten the work by using machines. These are all characterised by the attempt to tear the stump from the strong descending roots after the earth has been dug away, as previously explained. It is only in cases of small stumps and superficial rooting that digging can be dispensed with. Also where machines are used, they either tear the whole stump from the roots, or remove it piecemeal.

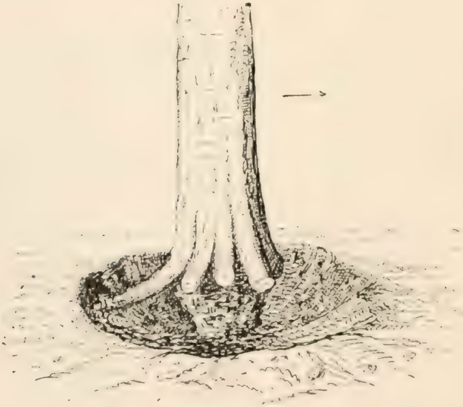
Wherever machines such as the **forest devil** are used for uprooting stumps, all the side-roots should be cut-off close to the stump, except one large side-root which is left longer than the others, and serves as a lever for the attachment of the implement, as shown in fig. 122.

FIG. 122.



Preference should always be given to the simplest of the implements which have been already described, and although they only partially replace manual labour, yet they afford a simple application of considerable power. Experience has shown that the forest-devil is the best of the heavier implements. The Hawkeye machine is more powerful, and would be used in preference were its cost not so high.

FIG 123.



(After Boppe.)

Objection has been made to the use of the forest-devil, that it requires too many hands to work it, that it is difficult to fix the rope, and that the long lever requires much space to work in. These difficulties are not, however, so great as they would appear to be, if a chain is used instead of a rope, and the roots are thoroughly exposed before working with the machine is attempted. Once this has been done, only three or four men are required to extract the stump, and in Silesia it has been found to save 33 per cent. of manual labour.

ii. *Uprooting Trees.*

When trees are uprooted (fig. 123) much of the stump is obtained with the stem, in the same operation. The roots are exposed by digging, and the stem is then thrown in different ways, but in all of them a thorough exposure of the roots is essential. If all the horizontal roots are then severed, the stem is attached to the ground by the taproot or main roots only. If, as with spruce on shallow soil, there are only horizontal roots, merely severing these suffices to fell the tree; but wherever there are strong deep-going roots which it would be a most laborious operation to sever, the work is effected as follows:— A rope is fixed, as high up as possible, on one of the main branches of the tree, and on that side of it towards which the tree is intended to fall. A number of men then tug at this rope, and by alternately pulling and yielding, they make the stem oscillate backwards and forwards. One man is left at the base of the tree to cut through any roots which may still resist, and to place poles under the base of the tree as it rocks, and prevent its return to the vertical position. In this way, without any great amount of trouble, the tree can be made to fall, tearing-out at the same time all the stronger roots.

The forest-devil, Wohmann's thrust-pole, and the common screw-jack may also be used to overturn trees by the roots. The mode of using these machines has been already explained, and is shown in figs. 116, 117, and 118, but in the case of the forest-devil a stem or stump must be at hand to be fastened to the implement, stronger than the tree which is to be overturned.

All roots on the side where the tree is to fall must be cut close to the stem in order to lighten the work, and it is a good plan to place a round piece of wood under the falling stem, so that by its own fall the latter may the more readily tear its roots from the ground.

iii. *Advantages and Disadvantages of Uprooting.*

The advantage of utilizing the stumps consists chiefly in the reduced waste of wood this involves ; for, on the average, one-fifth of the stem and branch-wood is contained in the stump. Stump-wood affords very good fuel, especially where a protracted steady heat is required. The demand for firewood is, however, frequently so small that stump-wood has lost much of its importance in this respect. In highly populous districts, it may be the object of a forest servitude, or roots may be extracted for cultivation of the ground. In other cases, stump-wood is used for the horns of sledges, as knee-timber for ships and boats, for ploughs, &c. Extracting stumps is also useful, as by afterwards levelling the holes, the ground becomes thoroughly cultivated and suitable for sowing ; for not only is germination facilitated, but in dry soils the young seedling-plants thrive best on the deeply worked soil of these holes, provided care is taken to protect them from weeds. Stumps are also frequently breeding places for destructive insects, especially of *Hylobius abietis*, *L.*, and shelter mice, and their removal is thus beneficial.

There are certain disadvantages involved in the removal of stumps, and in the first place, decayed stumps increase the humus and mineral matter in the soil. This may not be of importance where the humus is carefully preserved by maintaining the leaf-canopy and preventing all removal of litter, and especially on damp soils. Where, however, these conditions do not hold good, as for instance on poor sandy soil where the litter is removed, if the stumps are also extracted and the soil thus deprived of its last resource in organic matter, it may thus be rendered absolutely unproductive. Secondly, on steep slopes, wherever it is essential to hold the soil together as much as possible, in order to prevent denudation, extraction of stumps should be prevented.

Extraction of stumps is, therefore, permissible wherever it can be done remuneratively, provided that no serious damage is done to the standing-crop, as for instance by extracting stumps of large reserved trees among poles or saplings, or of mother-trees among thoroughly stocked natural regeneration: it is advantageous,—wherever there are blanks and gaps in natural regeneration, even in coppices, provided the loosening of the soil which accompanies the extraction of the stumps causes no local damage by floods, or on steep slopes by landslips or avalanches; wherever there is no fear of exhausting the productiveness of the soil, and wherever it is wished to prevent damage, by delinquents extracting the stumps, or by insects or mice.

The question now arises whether it is better to extract the stumps or to fell the trees by their roots. There has been much discussion regarding this, but there can be no doubt that uprooting trees is preferable. By this method, much wood which would otherwise be wasted, or become merely firewood, is kept on the stem and the roots are not only extracted more easily, but also more thoroughly. Stems uprooted also fall more lightly on the ground than felled trees; so that there is less breakage and damage done to young growth, and the roots attached to the stem are more easily converted into smaller material than in the case of a stump.

As regards the gain in timber, it is evident that a considerable and often highly valuable addition is thus made to the largest log in the tree. This may amount to 8 to 10 per cent. of the timber in the stem. All windfalls are in this condition, and generally fetch good prices.

It can also easily be shown that uprooting trees is a less laborious way of utilizing root-wood than the method of extracting the stumps, for it is clear that in both methods the earth must be dug away from the roots, whilst the only advantage of the machines is to save a certain percentage of the manual labour, which must be employed in extracting the stump. When, therefore, nature offers a lever in the tall stem of the tree firmly fixed to the stump to be extracted, its effect can be replaced by no combination of machines, so that it is mere folly to expect better results from the latter. The stem itself tears from the ground a number of small roots which could have been dug up only at a cost quite disproportionate to their value. It is also always easier to separate the stump from the stem, after the tree has been felled, than while it is standing. According to experiments carried out by R. Hess, there is a gain in time and labour of 20 per cent. in uprooting trees instead of felling them and then extracting their stumps.

The advantages thus described of uprooting the trees are sufficient to entirely counterbalance the alleged disadvantages of the method. It is stated, for instance, that the tree cannot thus be thrown with certainty in any desired direction, but by using a thrust-pole, or a rope, and carefully severing any resisting roots while the tree is falling, it can be thrown quite accurately. Another objection is made, that the falling stem frequently tears-up a large mass of earth with the roots, a statement often made erroneously and in any case not sufficiently objectionable for the uprooting of trees to be abandoned. A larger hole is often made by grubbing-out the stump than by uprooting the tree. It is also alleged that uprooting trees seriously delays the felling operations. The sub-aërial part of a tree is clearly utilized more quickly by the use of axe and saw than by uprooting the tree, but if the subterranean part is required as well, there can be no advantage in setting to work on the felling-area a year after the trees have been felled in order to extract the stumps.

Whilst, however, it is in general preferable to uproot the trees, cases occur where grubbing-out the stumps is necessary or permissible; as for instance where felling is urgent but the ground is frozen, and in forest clearances, where there is no urgency for extracting the stumps. It is always pre-supposed that extracting stumps is done by the aid of implements, for when this is done by mere manual labour, it is the most tiresome and dilatory mode of utilizing the roots of trees.

[Wherever a clearance is to be effected for a forest-road, or ride, or for the site of a nursery or forest-house, &c., it is always better once for all to uproot the trees standing on the area.—Tr.]

3. *Felling Rules.*

Partly as regards care for the forest growth, partly to increase the quantity and value of the yield, and partly to economise labour, the following rules should be observed by woodcutters.

i. **The woodcutter must always endeavour to throw every stem, so that by its fall it will do the least amount of damage to the forest growth and felled timber around it.**

The attention of the woodcutter in this respect is particularly necessary in the case of the final stage in shelter-woods, selection-fellings and in all reproduction-areas, and wherever large trees standing over poles or saplings are to be felled.

In order as fully as possible to carry-out the rule, the directions of the forest officials should be closely followed, so that the young growth may be injured as little as possible. To secure this object, it may be necessary to lop all the branches from large trees before felling them.

The skill and attention of the woodcutters are nowhere put to such a test, as in the removal of large trees from over poles and saplings in the natural regeneration-fellings under the group system. The more susceptible to damage the young crop, the more careful should the woodcutter be, and the more important it is to effect such fellings **gradually**, that is to distribute them over several years, and to choose a season for the felling when the young growth is least brittle and least liable to damage by the unavoidable accidents contingent to fellings: in any case such fellings must never be undertaken during frost.

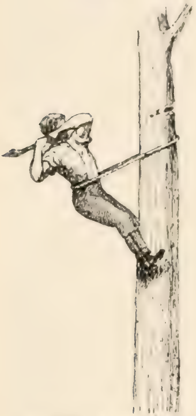
Secondary fellings over young seedlings are also highly dangerous to the young growth, and should be effected only when sufficient snow is on the ground to protect the plants.

The lopping of branches from standing trees may secure several objects. It sometimes assists the fall of a tree in a certain direction to lop the branches from the opposite side of the tree, but the chief reason for lopping the branches is that the tree in its fall may do as little injury as possible to the young growth.

Whether this lopping is necessary or not depends on several circumstances. In the first place, it must be remembered that it is not the stem, but the crown of the tree which may do serious injury to the young plants. If, therefore, it can be arranged to throw a tree with its crown on a blank unstocked with young growth, there is no need of lopping its branches. In such cases several trees may be thrown with their crowns on the same blank.

Lopping the branches of a tree is dangerous, and men capable of doing it are not always available, so that the forester will if possible avoid the practice. In certain regions, as in France, the Black forest and many Alpine forests, experienced climbers who mount the trees with climbing-irons (fig. 124*a*), may be found ready to do the work, on account of the high rate of remuneration. Wherever a coniferous tree standing over a group of young conifers is to be felled, its stem should always be first completely cleared of branches, and the narrow alley it makes in the young wood will soon become closed. This is especially desirable in coniferous forests, for injured advance-growth is very liable to insect attacks.

Fig. 124.

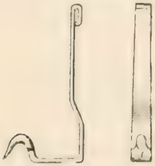


Removing top of tree.
(T. H. Monteath.)

Lopping the heavy boughs of broad-leaved trees standing in the midst of young growth may injure the latter, whilst the entire crown might fall beyond them, and in any case not injure them so much as the separate boughs.

[The branches and top of very tall oaks and beech are, however, often lopped in France, in order to prevent their long valuable stems which are much lighter without their lofty crowns (fig. 124), from cracking in their fall.—Tr.]

Fig. 124*a*.



Climbing-Irons.
(After Boppe.)

Valuable little stems in pole-woods may often be bent back, or tied back by withes to allow for the passage of the falling stem. It is, however, an error to be too anxious to prevent damage to young growth in a felling, for everyday experience shows that what appears to be serious devastation is no longer noticeable after a few years. Even where a valuable standard tree standing over large poles has become mature, no hesitation should be shown in felling it.

ii. Each stem should be thrown in such a direction that it does itself the least amount of harm.

As regards the direction for felling on slopes, the danger of breakage is much lessened by throwing the tree uphill, as then its summit describes the smallest arc and attains the least velocity on reaching the ground. Therefore, in felling valuable tall timber trees, it is better to fell uphill. On very steep slopes it may be advantageous in the case of firewood trees to throw them with the crown downhill, so as to prevent the tree from sliding any further.

[In the Himalayas, however, the plan of felling uphill was abandoned in steep places owing to the danger this caused to the woodcutters, the base of the tree often shooting out backwards or sideways from the stump. This danger may be avoided by felling sideways, on to a contour line, if the men stand above the tree at the moment of its fall.—Tr.]

In order to prevent the stem from breaking, the configuration of the ground on which it will fall should be carefully inspected, as felling across gullies, on to rocks or other stems may break the tree. In the case of valuable timber, where there is an object in securing as long and straight pieces as possible, or where valuable curved wood is being felled, great care must be taken not to throw the tree on to stones or frozen ground, and therefore felling valuable trees should be stopped during a hard frost.

In such cases a soft bed of branches or faggots may be placed under the trees, on to which they should be felled; or they may be felled against a neighbouring standing tree, provided that it is also to be felled. A tree may also be felled, so as to fall slowly, by forcing it over by means of wedges before it is completely severed from the stump. Where a tree is not too tall, it may preserve the lower part of the stem from breakage, to fell the tree without previously lopping any of its branches.

iii. In felling timber-trees, attention should be paid to easy removal of the logs.

Such trees should not, therefore, be felled across or into ravines, but, provided rules i. and ii. are observed, into such a position that its removal may be easily effected.

Long stems are most easily removed downhill, when they lie along the slope of the hill with their thicker ends downwards, and this position is secured by throwing them uphill.

iv. **During a strong gale, felling operations must be suspended.**

This should be attended to, at any rate, wherever the direction in which the trees will fall is of importance, for the woodcutters are then no longer able to guide the trees.

The wind is the woodcutter's worst enemy, and it is usually during a gale, which prevents the men from hearing what is going on around them, that most felling accidents happen. In felling a tree, the woodcutter is safest near the stump and at right angles to the direction in which the tree will fall; the most dangerous place in felling uphill is behind the stump, as already explained, especially in the case of crooked trees.

v. **Great care must be taken that no trees intended to form a shelter-wood, or otherwise not to be felled, are injured by the fall of the trees marked for felling.**

If such an accident should happen, a few marked trees should be left unfelled from which the forest manager may choose substitutes for those injured. This should also be done in case windfall or theft has removed any of the selected shelter-trees. Poles or saplings bent by the felling should, if possible, be set straight, or if too much injured for that, should be cut-back level with the ground, with a sharp instrument.

Whenever a tree falls out of the proper direction, it frequently happens that it rests or remains hanging on another tree. Such a tree may usually be brought to the ground, by cutting it away from its stump, to which it is often still attached in such cases; or one or two short logs may be cut away from its base; or use may be made of the screw-jack to release it. If, however, no other means of releasing it are available, a man must climb the trees on which it is resting and lop off the branches which impede its fall.

[In tropical countries, where large woody climbers abound in forests, these should be severed near the ground, two years before felling, so that the stems of the climbers which frequently enlace several trees may become rotten before the felling takes place; otherwise a whole group of trees may have to be felled at once, if it is desired to fell any of them.—Tr.]

vi. **Trees exceeding 6 inches in diameter, chest-high, should always be felled with the saw and axe; smaller trees and very large trees may be felled with the axe alone.**

In all cases the cut should be as near the soil as possible, and, as a rule, the height of the stump should not exceed the third of its diameter, or say one foot for large trees and six inches for small ones. Exceptions, however, occur to this rule: thus in the Harz, stumps three feet high are left, as they make the best charcoal for blast-furnaces; in other places forest rights compel the managers to leave high stumps. [Mahogany and other tropical trees which have large buttresses rising from the roots are felled by erecting platforms above these buttresses.—Tr.] Wherever the trees are uprooted, care must be taken that this is thoroughly done, so as to save all rootwood over 1¼ inches in diameter, and the holes made in the ground must be carefully filled again.

vii. **Wherever coppicing is effected, only the axe or billhook and not the saw should be used, in order that smooth surfaces not liable to decay may be left to the stools.**

The cut surface should be quite smooth and the stools must not be split, nor the bark torn from them; poles and saplings must not therefore be bent over by the woodcutters whilst they are being cut, and every woodcutter must use sharp tools.

In the case of all trees which reproduce by suckers (elm, white alder, lime, aspen, common maple, hazel and most willows) and of those which shoot out from collum-buds, provided the stools are not very old, the cut should be as deep into the ground as possible. In this way the shoots will come out close to, or even below the surface of the ground, and will produce new roots for themselves, and thus new stools will be formed. The beech, on the contrary, shoots high up on the stool; for beech, therefore, for alders in ground liable to inundations, and for birch on poor soil, each successive felling must be made slightly higher than the previous one.

The yield of a coppice is maintained only by preserving the strong old stools; young seedling plants do not compensate for the death of these. Old stools may be kept productive for long periods, if they are cut somewhat higher at each felling. If stools get covered with moss and knobbed, they may be left up to six inches high in the case of beech and other species which do not produce suckers. Oaks and hornbeam, as a rule, are least sensitive to bad coppicing. In the case of pollards, the cut is generally slightly raised at each felling.

viii. **Woodcutters, as a rule, should not fell more trees than they can convert and remove in the next three or four days.**

This tends to facilitate order and supervision, and also to economise labour, for otherwise not only would they have insufficient space in which to work, but also encroach on the space of neighbouring parties, whilst the removal of the wood would be delayed till all the felling was over. Only in the case of thinnings or clearings should all the trees first be felled and then converted into marketable sizes.

ix. **Whenever there is fear of damage by insects or fire, the woodcutter is bound to clear away all wastage of broken branches and twigs from the felling-area.**

Wherever the brushwood cannot be otherwise utilized, as in remote mountain-forests, it should be collected in heaps, leaving room between these for the removal of the timber. After the felling is over, the brushwood is often spread over the area to protect the young growth from frost, heat, and cattle, or it is burned.

x. **Wherever breakage has occurred, owing to wind or snow, the work cf felling should commence on the side of the prevailing wind and proceed in its direction.**

Clearing extensive areas covered by windfalls is often a most dangerous occupation for the woodcutter. Trees crossing one another and wedged together can be separated only with the greatest difficulty, whilst when a stem has been cut from its roots and the attached ball of earth, the latter may suddenly turn over, and accidents can only be avoided by great care and attention on the part of the woodcutter.

SECTION V.—ROUGH CONVERSION OF WOOD.

By rough conversion of wood is meant the wood-cutter's work of dividing felled trees into pieces of dimensions suitable for transport. Any further preparation of the wood into marketable pieces is usually the work of the timber-merchant or middleman.

No part of the work on the felling-area is more important than rough conversion, or requires greater supervision and care on the part of the forest manager, for it has a very great influence on the forest revenue.

In order that a forest may be managed so as to satisfy the demands of its owner, as well as of the neighbouring population, it is necessary in forestry, as in all other branches of industry, that every endeavour should be made to utilize the raw material completely and in all possible ways, and thus meet the actual requirements of the public. The trees must therefore be converted into timber from an entirely mercantile point of view.

As a last resort, all timber can be used as firewood; whenever then it is only fit for fuel, the business of conversion is reduced to the simple operation of preparing the usual sorts of firewood.

Since, however, in most districts the value of firewood has of late years been greatly reduced, and a revenue can only be obtained from many forests by sale of the timber which they produce, the most important point here is the conversion of the latter. The chief rule is, therefore, to produce as much timber of good quality as possible, and in order thoroughly to attain this object, a forester must have a certain knowledge of the requirements of the different industries where wood is used.

The subject will be dealt with as follows:—first, the circumstances which decide on the kind of conversion to be applied; then the usual assortments of timber and firewood and the modes of conversion adopted by the wood-cutter; and, finally, the general principles of rough conversion.

1. *Mode of Conversion to be Applied.*

The mode of conversion suitable to any particular felling-area depends on the **adaptability of the wood** and **the demand for it**.

(a) **The Adaptability of the Wood**.

This varies with the kind, form, dimensions and quality of the wood.

i. *Kind of Wood.*

The uses of the different kinds of wood have been already discussed ; it has been shown that conifers are chiefly used as timber and that, of broad-leaved species, it is the light-demanding trees, and, above all, the oak, which yield the most valuable timber.

The following remarks refer to the usual forms of woods met with. Pure beech high forest is generally a fuel forest, and only a small portion of the yield can be treated as timber. Sometimes, owing to a favourable market [as, for instance, in the chair-making districts of Buckinghamshire and Oxfordshire, or in the Ardennes for wooden shoes, &c.—Tr.] this is not the case ; but frequently the timber yield of a pure beechwood is not more than 10 to 20 per cent. of its total yield.

Wherever aspen, birch, willows, limes, &c., are mixed with beech, there is a rise in the timber yield, but this can only be considerable when oak, ash, sycamore, or elms are mixed with the beech. Such mixtures are the most valuable forms of broad-leaved high forests, as in them the light-demanders thrive best and attain their best shape. The timber yield of such forests may be 20 to 30 per cent. of their total yield, and even more.

In the Rottenbuch forest range, which is the range richest in fine oak trees of the whole Spessart, the yield of oak-timber between 1860 and 1880 was 26 per cent. of the total yield.

The yield of oak-timber does not depend so much on the quantity of oak-trees in a mixed wood as on their age and soundness, and throughout the renowned oak-forests of the Spessart usually only 40 per cent., or at most 50 per cent., of the felled oak-trees can be used as timber, the remainder usually yielding only inferior firewood.

Pure alder-woods yield chiefly timber, but are, unfortunately, decreasing in area, though greatly esteemed for the manufacture of cigar-boxes. [In Britain they yield gunpowder charcoal and clog-wood.—Tr.]

It is rare to obtain more timber than firewood from broad-leaved forests; the contrary prevails in coniferous woods, and wherever conifers are grown, mixed with broad-leaved trees, they form splendid trees, and the yield of such forests in valuable timber is very high. Woods of spruce, silver-fir, and Scotch pine [also larch in Britain.—Tr.] or mixed forms of these with beech as a subsidiary species are the chief kinds of coniferous forests in Europe.

In the case of spruce and silver-fir woods, the timber yield may, under favourable circumstances, go up to 75 to 80 per cent., and exceptionally be even higher; in good Scotch pine forests, up to 55 to 70 per cent., whilst in the north of Europe their yield in timber may equal that of spruce and silver-fir.

Coppice-with-standards, on good soil and well stocked, yields fine timber, and is the only system capable of yielding oakwood of best quality for shipbuilding.

Coppice yields chiefly firewood, and also small wood required in agriculture, such as hop-poles, vine-props, hurdle-wood, laundry-props, orchard and garden tree-props, crate-wood, bean and pea-sticks, fascines and osiers. Also much pit-wood for mines.

ii. *Shape of Trees.*

As a rule, large dimensions in length and diameter, and straight and cylindrical stems, are required for the best timber. A large diameter is generally more important than great length, and it is trees of large diameter which are most saleable at present.

As this implies long rotations for even-aged woods, the yield in timber of such woods naturally increases with their rotation, up to a certain point.

In uneven-aged woods, where there is an inferior stage of trees below the more valuable ones, the latter may attain their largest dimensions in diameter, and cylindrical shape. Although, as stated, the yield of timber from a wood increases with its age, it must not be supposed that the poles which are the produce of thinnings are not utilizable as timber (for paper-pulp, pit-props, &c.). As a rule, the best timber should be as straight as possible: the demand for crooked and curved timber required for ships, boats, wheelwrights, saddlers, &c., is only produced by standards over coppice or hedge-row trees; but since timber is bent artificially, the demand for it has been reduced.

iii. *Quality of the Wood.*

The first enquiry should be to ascertain whether or not the wood is perfectly sound, absolute soundness being the first condition of the admissibility of wood as timber; this should be most carefully investigated in the case of trees from old woods, whether broad-leaved or coniferous, which are destined for long water-transport, and may not be carefully treated in the timber depots. The grain of the timber should be next considered, whether it be coarse or fine-grained, knotty or free from knots. The mode of disposal of timber from Scotch pine, larch, and oak, is affected by the quantity of heartwood the trees contain, also by the fact that its fibre is straight or twisted, splits easily or with difficulty, its stem more or less cracked, containing cup-shakes, &c.

From what has been already said in the second part of the book, it is evident that the quality of a timber will govern its future mode of utilisation.

Local defects in a stem may render only a part of it useless for timber, and this is especially the case with oakwood and other valuable woods. In converting such wood, therefore, great care must be taken to utilize fully all the good pieces.

The present market-prices for sound, straight-fibred wood are at least 30 per cent. higher than for wood of ordinary quality, with which the market is glutted. For certain industries the structure of the annual zones of wood and its grain are of the highest importance, as in wood for musical instruments and mast-wood, also in the grain of fancy woods for furniture. The degree of fissibility is also highly important, especially in extensive coniferous forests, where a very large amount of the annual yield of wood is split into various wares, and, in the case of oakwood suitable for staves. In some forests, as in Bavaria, the trees are examined as to their fissibility before being felled, by trimming off a patch of their sapwood. Not every kind of heart-shake will render a tree unsuitable for timber, and even a heart-shaken tree may be sawn into planks provided the shake is in a line right through the core of the tree ; heart-shakes also are often confined to the base of the tree, and may be disposed of by sawing one or two short logs from it.

Cup-shake and twisted fibre may however render a tree unfit for timber.

(b) Demands of the Market.

The mode of conversion to be undertaken also depends on the demands of the market. For wherever there is no demand for any sort of converted timber, or for any timber at all, it is evident that only firewood will be prepared. The demand is measured by the price, and wherever any assortment of timber fetches a higher price than firewood it is evident that conversion into timber should result. The rule should therefore be to produce as much good timber as can be profitably utilized, without including the smaller sized material resulting from thinnings with which the market is soon glutted.

Wherever there are forest rights to firewood, the outturn in timber is limited by their demands, and frequently, if such rights cannot be compensated in money, wood of the best quality has to be sacrificed to meet these demands.

On the average in the different German countries, the production of timber is only really large in Saxony, and was as follows in 1885 :—

COUNTRY.	PERCENTAGE OF WHOLE YIELD.	
	Timber.	Firewood.
Hesse	25	75
Alsace-Lorraine	33	67
Prussia	37	63
Baden	38	62
Bavaria	42·6	57·4
Württemberg	47	53
Saxony	80	20

These figures are not however all prepared on the same basis, as in Saxony all wood used for paper-pulp (60 % of the total yield) and mine-props is rightly classified as timber, though only as firewood in other countries.

2. *Timber-Assortments.*

It is evident that the woodcutter cannot generally undertake to prepare timber for the market in the ultimate form it assumes when taken over by the different industries. This would require much too extensive a knowledge of the latter.

As a rule, therefore, it suffices to divide the trees into transportable pieces which by their dimensions and qualities are suitable as the raw material of an industry, or a whole group of industries. The further detailed conversion may be left to the special industries, or to the wood-merchant. In small private forests, however, matters may go further in this respect.

[The best example in Europe of detailed conversion as well as labour-saving means of transport may be seen in the Sihlwald, belonging to the town of Zurich, where under Forstmeister Meister, the wood is converted on the spot into all kinds of commodities, down to wood-wool for packing.—TR.]

The various pieces into which a tree may be converted by the woodcutter are termed rough assortments of timber, and may be distinguished as follows:—

TIMBER.	FIREWOOD.
Logs	Split billets.
Butts	Round billets.
Poles	Root and stump billets.
Stacked timber	Faggot-wood.
Brushwood { Material (beansticks, &c.) from the crowns of tree, from young thinnings and coppice fellings, other than faggot-wood.	

(a) Timber.

Besides the assortments described on pages 106–111, according as the timber is in logs, planks and scantling, or cloven, timber has been popularly distinguished according to its destination for building purposes, manufactures or agriculture.

Building-timber is used in superstructures, bridges, embankments, mines, roads, railways, or in ship and boat-building.

Manufacturers' timber is used in all ordinary wood-working industries, such as cabinet-making, carriage- or cart-building, turnery, wood-carving, coopers' work, &c.

Agricultural timber is used for gates and fences, hop-poles, hurdles, stakes, pea and bean sticks, &c.

From a careful consideration of the distinction between the different kinds of timber available, a forest manager will readily perceive how his trees should be converted in order to meet these various requirements.

Wood from stems is usually classed as logs or butts. The distinction between stems and poles and between logs and butts varies in different forests, but the following classes usually occur in the timber-trade.

i. *Logs.*

Logs are the boles of full-grown trees, or the greater part of them, after they have been topped and freed from branches. Logs should measure at least 23 feet (7 meters) in length, and their mid-diameter should be at least 6 inches (15 centimeters) without bark, including the bark 7 inches (18 centimeters).

In most cases the longer and straighter the logs and the greater their diameter at the smaller end, the greater is their value. Logs are used chiefly in the different building-industries, but also to a small extent for implements, sails of windmills, stamping-hammers, &c.; as cloven-wood, for which only straight-fibred timber is admissible, they are rarely required in full length; as sawn material they are used chiefly in shipbuilding, for planking, &c.

ii. *Butts.*

Butts are round pieces of stems or of exceptionally large boughs, usually cut from the shorter and thicker part of either. A butt should be less than 23 feet (7 meters) in length, but at least 7 inches (18 centimeters) in mid-diameter measured without the bark. Whilst therefore in length a butt is surpassed by logs, its chief value lies in its larger diameter.

Butts are used for piles, mining purposes, railway-sleepers; shorter pieces (partly curved) in shipbuilding; also in the construction of bridges and roads. In machinery they are only slightly in demand for rests, or sockets, anvil-stocks, pounding-troughs, &c. They are largely used as cloven-wood by the stave-maker, cooper, wheelwright, turner, shingle-maker, &c., also for wood used for musical instruments, gunstocks, &c. Butts are, however, chiefly used for sawn timber, and the bases of coniferous stems to form butts for sawmills in lengths of 10, 12, 14, 16, 18, 20 and 22 feet, those from 12 to 16 feet long (3½ to 5 meters) being preferred.

Wood of oak, beech, poplar, alder for cigar-boxes, and other kinds, are also cut into butts of similar dimensions for sawing.

iii. *Poles.*

Poles are young stems, generally the produce of thinnings or coppice-fellings, and usually measure less than 7 inches (18 centimeters) in mid-diameter, being always measured unbarked. They are usually sold at their full length for pit-props, shafts, ladders, hop-poles, tree-props, bean-sticks, &c. They may also be split into crate- or hurdle-wood, but are very rarely sawn into scantling.

iv. *Stacked Timber.*

This is in the form of round or split pieces, which are piled like cordwood and sub-divided into 2 classes—

Pieces over 6 inches (15 centimeters) in mid-diameter.
Pieces 2¾ (6 centimeters) to 6 inches in mid-diameter.

Stacked timber is used by the wooden shoe maker, cooper, wheelwright, turner, stave-maker, and in many places worked into vine-props. Round pieces are now chiefly used for making into paper-pulp.

v. *Brushwood.*

Wood less than 3 inches (7 centimeters) in diameter at the thicker end is termed brushwood, and is generally piled between stakes. It is partly branchwood, but chiefly the produce of coppice, and is used for fascines, pea-sticks, brooms, fencing material, &c. In the case of osiers it is used for basket-work.

(b) **Firewood.**

After all the wood which can be used as timber has been prepared, what is left is firewood.

Firewood is stacked for measurement, and termed cordwood. In Germany, Austria-Hungary and Switzerland, the usual length of pieces of cordwood is one meter, or 39 inches, but this measure is not compulsory, provided the volume is computed in cubic meters. [In Britain the length of billets is usually 3 feet.—Tr.]

Firewood is distinguished as follows according to the shape and size of the pieces :—

i. *Split Billets.*

Split firewood comes from stems and branches measuring across the smaller ends at least 5½ inches (14 centimeters), in Switzerland, 4½ inches (12 centimeters).

A piece of split firewood should measure from 5½–8 inches (14 to 20 centimeters) along the chord of its larger end, and exceptionally up to 11 inches (28 centimeters), and should always be split from the core of the tree.

ii. *Round Billets.*

Round firewood billets are unsplit round pieces of wood 2½–5½ inches (7—14 centimeters), in diameter at the thin end. In many districts, wood of this class is split in half. Round pieces of larger dimensions are sometimes used in charcoal-making.

It is always advisable to split the round pieces of firewood, in order to ensure drying, reduce carriage and increase the heating power of the wood. Experiments have shown that round firewood when split loses 27–28 per cent. more weight in the five winter months than unsplit wood, and Schuberg has proved experimentally that its loss in weight in four weeks' time is double that of unsplit firewood.

iii. *Stump- and Root-wood.*

Pieces of stumps and roots of all sizes, provided they are not longer than the other pieces of cordword and may thus be conveniently stacked, form this class of firewood.

iv. *Faggot-wood.*

Faggot-wood includes all refuse crown, branch, and coppice-wood under $2\frac{1}{2}$ inches (6 centimeters) in diameter at the larger end.

This is either piled in heaps about equal in size, or tied into bundles termed faggots, which are of about the same length and circumference as split cordwood billets. The remaining refuse of the felling is collected in heaps, and may be given away to the workmen, or auctioned.

3. *The Work of Conversion.*

The work of conversion comprises the woodcutter's work of preparing the different assortments just described from the felled trees, and demands the greatest care and supervision on the part of the forest manager.

(a) **Conversion of Timber.**

i. *Removal of Branches.*

The felled tree is first freed from branches from its butt upwards, the axe, or lopping-axe with a thick back, being generally used for the purpose.

The branches must be severed smoothly close to the stem, and all projections on the stem and stumps of branches removed. If the branches are large enough to make cordwood they may be sawn into suitable lengths whilst still attached to the stem. In other cases, and where it is preferable to use the axe, the branches may be cut from the stem and placed aside while the woodcutter is occupied with the stem. Whilst one man of a party removes the branches the others shorten the stem. In most cases the branches are only fit for firewood, but wherever some of the boughs in the large crowns of certain trees can be used as timber they should be carefully set aside, as pieces of valuable curved and kneed wood may be thus secured.

In the case of oak-trees the portion of the stem above the insertion of a large bough is so reduced in diameter that the stem should be severed at this point. The top is so much the more valuable if it forms a knee with an upper bough.

Knee-pieces may also be obtained from a portion of the base of a tree and of a strong root, if the tree has been uprooted.

ii. *Measuring the Stem.*

Once the stem has been freed from branches it is measured with a yard or meter measure, and the different yards or meters marked on it by slight cuts in the bark. If the stem is only fit for fuel it is then sawn through at these points (or into other short lengths); if intended for timber, it is cut into suitable lengths according to circumstances.

iii. *Determining the Assortment.*

Once the tree has been freed from branches, and measured, it must be decided from a consideration of its species, dimensions, form, and quality, and the demands of the market, into what assortments it will be converted. This decision is of the greatest importance, and should usually be made only by one of the forest staff. The usual rule is to allow the stems fit for timber to retain their full length as much as possible. There are many exceptions, however, to this rule, which is more applicable to coniferous than to broad-leaved wood.

(α) **Quality.**—Only perfectly sound wood should be converted into timber. This rule is specially applicable in the case of oak-wood, which is often full of defects. Large old beech, spruce and silver-fir trees are also often heartshaken, cracked, infected with red-rot, or brittle at the base of the stem. Wherever pieces of timber of doubtful soundness, or from which the defective parts have not been carefully removed, are offered for sale, future sales of timber are greatly prejudiced. When, therefore, there are any doubts as to the soundness of the wood, it is better to cut it into shorter pieces than to send suspiciously looking goods to the market. The timber purchaser, now-a-days, has had too much experience of such pieces.

(β) **Shape of Stem.**—Wherever long pieces are in demand, it is unusual to include in them the small end of the stem. The next point is, therefore, to decide where the top should be cut; as a rule, this should be wherever there is a marked falling-off in size, or a change of shape, in the stem—wherever, in fact, the top of the stem may be utilized differently from its lower portion.

By leaving a piece of wood at the end of a log which does not accord well with it the value of the latter is not increased, for the purchaser always excludes this piece from his estimate. If, however, the forest owner cuts off such a piece, it will at any rate be utilizable as firewood, and in the case of oak may be used as a railway-sleeper or gate-post, the value of which would not be considered by a purchaser of the bole.

Straight, long pieces which are chiefly coniferous need not, after removal of their end-pieces, be further shortened, and this is also the case with sound oakwood, even if not quite straight. In such cases, the longer the log the more valuable it will be. But as regards coniferous wood further consideration is necessary. Logs are sometimes sold by length and a fixed minimum diameter of their smaller ends, and this should be the universal rule with coniferous timber. In such cases, the best place for removing the end of a log is where the small-end diameter approaches as nearly as possible to the minimum admissible. This is rarely less than 6 inches for logs, and it may be laid-down as a general rule, that the small-end diameter of a log should be one-third of that at its base.

In the case of trees from coppice-with-standards the crown usually contains most of the wood, and the stem must often be cut much shorter than its entire length.

(γ) **Demands of the Market.**—There are districts where long logs are not in demand, but butts for sawmills are preferred, and the finest spruce-logs are cut into suitable lengths for the neighbouring sawmills; where fine, straight oak stems must be cut into short lengths for staves, and so on. In other districts long logs are required for floating. In such cases, the custom of the trade must be followed in converting the timber. It should also be considered whether, or not, the customs of the market are stable, the former being frequently the case in districts richly supplied with sawmills, and more so with coniferous than with broad-leaved wood. In other cases, and especially with oak-timber, the demands of the market are very variable, depending on a good vintage, on large imports of foreign timber, &c. In such cases it is prudent to cut the logs as long as possible, provided they are sound.

In other districts, where timber is chiefly used for local purposes and both short and long logs are wanted, it is better to cut one or two butts for sawmills from the base of the stems and retain the remainder as long as possible for building purposes. A prevalent demand for long logs will occasionally modify this rule and decide on the number of sawmill butts which will be sawn from the stem. It is not, as a rule, financially advisable to prepare butts for sawmills of less mid-diameter than 12 to 13½ inches (30 to 35 centimeters); small butts may, however, be split or sawn, into laths.

(δ) **Facilities of Transport.**—In converting large standards over a dense growth of saplings or poles, it is often considered best, out of respect to the young wood, to cut them into short lengths. Exceptionally this may be justifiable, but should usually be avoided, for the standard was retained expressly to yield large timber.

All shortening of stems should be done with the saw, and only long logs which are to be dragged along the ground, slid down-hill with ropes or floated in rafts, should have their larger ends rounded with the axe.

iv. *Exposure of Defects.*

All wood, and especially pieces of valuable timber, should be so exposed by cutting through all swellings or overgrown knots, as to show its inner quality, and increase the confidence of the purchaser.

In the Spessart, and for the Baltic trade, oak-logs are split down the centre into half balks, so as to completely expose the interior of the wood.

v. *Prepare the most Valuable Assortments.*

Wherever stems may be converted in several ways, that way should be adopted which is expected to yield the best price.

vi. *Conversion of Poles.*

Poles suitable for pit-props, hop-poles, cart-poles, telegraph-posts, ladders, shafts, hurdles, bean-sticks, &c., which come partly from the principal fellings, but chiefly from thinnings, present the least difficulty in conversion. The species, and the greatest possible degree of straightness, are the chief points to be attended to.

In some cases it is necessary to leave the poles quite unshortened, as for hop-poles, where the branches are not lopped off close to the stem, but snags of branches are left to assist the climbing of the hops. Sometimes the tops are left, as a proof that the poles were not dead when felled. Clothes' props, and props for trees, are also left forked at the top. The top is removed from cart-poles.

Fig. 125.

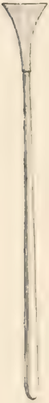


Fig. 126.

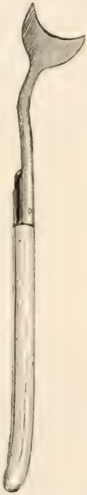
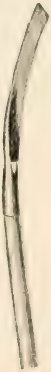


Fig. 127.



The dimensions of the different assortments vary locally.

Thus, hop-poles may be between 16 and 30 feet (5 and 10 meters) in length. Telegraph-posts should be 7 to 10 inches (18 to 25 centimeters) in diameter, at one yard from the butt-end;

hop-poles 2½ to 5 inches (6 to 12 centimeters). Hop-poles are generally felled deep into the ground with the axe, whilst ladder-wood and wheelwright's wood should be sawn straight at the butt.

vii. *Removal of Bark.*

All stems felled in coniferous forests during summer are usually barked to prevent insect-attacks, facilitate transport and preserve the white colour of the wood. The wood may be completely barked, whenever this can be done, as in spring and early summer. During autumn and winter the bark can only be partially removed.

Although complete barking gives the wood a better appearance, yet the rapid drying which ensues frequently causes numerous cracks, into which spores of fungi are conveyed by the rain, and then the timber is liable to decay unless rapidly transported to its destination.

In this respect partial barking is superior. The tools used for barking are shown in figs. 125, 126, and 127, and they save 50 per cent. of labour when compared with the axe. Large stems with rough bark, especially during winter, are usually barked with the axe or adze.

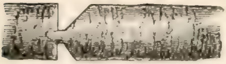
It has recently become usual also to bark the larger poles and especially hop-poles. Here only partial barking is necessary.

(b) **Preparation of Firewood.**

Firewood, and especially split and round firewood, is prepared from the remains of the stem and branches after conversion of the timber; or whole firewood trees, as in beech forests, are freed from branches, marked-off into lengths, and then sawn into short butts.

In cutting-up butts for firewood the curved saw is chiefly used, and the work is assisted by wedges, which are inserted as soon as the saw-cut is deep enough. Woodcutters must be careful not to cut obliquely, as they may easily do by mistake on sloping ground. The cut must be at right angles to the axis of the tree, if the cords of firewood are to have a good uniform appearance. As a rule, the larger branches are also cut into lengths with the saw, which should be used wherever possible in converting wood. Only on very steep, rocky ground, where the workman cannot find room to use the saw, or when stems are lying one over the other, &c., may the axe be used for this purpose. The wood should then be cut so as to have one cut vertical and the other oblique, as in fig. 128. By the use of the axe from 6 to 8 per cent. of the wood is wasted, being 7 per cent. when the pieces are 1 meter long.

Fig. 128.



The round pieces over 5½ inches in diameter at the smaller end are then split by means of the wedge and cleaving-axe into split cordwood, and whenever the trade prefers that round cordwood should be split, this should also be done.

The wedge is generally placed on the top of the round piece, and driven in by a blow of the axe-head. Whenever the wood is difficult to split this forms the chief part of the woodcutter's work in the preparation of firewood. He requires several wedges of different sizes, and even uses the cleaving-axe as a wedge, driving it in with the beetle. It is only in the case of easily split wood that the wedge may be placed on the side of the round pieces.

Pieces 5½ to 8 inches (14 to 20 centimeters) across are usually merely split in half, whilst pieces 8 to 12 inches (20 to 30 centimeters) across are split into 6 or 8 pieces. Except in the case of very large trees, the pieces are always split to the core. It would, however, be better, both to facilitate transport and improve the quality of the wood, that no pieces exceeded 5½ to 8 inches (14 to 20 centimeters) measured along the chord.

(c) **Refuse.**

Pieces too knotty or of too twisted fibre to be split remain entire and go with the refuse, after the conversion is over.

(d) **Cloven-timber.**

In the conversion of firewood, billets which may be otherwise utilized should be carefully put aside. This is specially necessary with oakwood; and from the broken pieces of trees which cannot be converted into logs, or butts, many billets may be utilized as cloven-timber, and they should be carefully freed from all defective portions and from sapwood. They need have no fixed dimensions, but should be as large as possible and of whatever length is desirable.

(e) **Conversion of stumps and root-wood.**

The most laborious of all works in conversion of wood is that of the stumps and roots. If the tree has been uprooted, the roots are separated from the stem by means of the saw, and they are then freed from the soil which may be attached to them and reduced in size by means of the wedge and axe, or by blasting them with powder or dynamite.

In separating the roots from uprooted trees, it sometimes happens, in easily cloven wood, that when the saw has gone about half through the base of the stem, the stump splits the stem owing to its weight and falls back into its original hole. To prevent this disaster, a chain may be wound round the stem below the saw-cut and tightened by driving in wedges, and the stump supported by pieces of wood.

i. *Conversion of Stumps by means of Ordinary Tools.*

Small stumps up to 3 inches across are not split. Those from 3–6 inches are split lengthwise by means of the axe and wedges, the wedges being usually placed on the sawn section, and if it is also necessary to begin splitting from below as well, always from the projection of a side-root, where the stump is most easily cloven. If possible, the wood should be split to the core, but this cannot be done in the case of thick stumps of coarse fibre, from which pieces are split-off gradually from the circumference. This method of splitting is more easily effected while the stump is still in the ground, than after it has been extracted. Wooden wedges, holding better than iron ones, are more serviceable in splitting stumps. In order to tear the pieces more thoroughly apart, iron crowbars are used, and the ordinary screw-jack is very serviceable. It has already been stated that machines may be used for splitting stumps.

ii. *Blasting Stumps by Gunpowder.*

The stump which is to be blasted by a charge of gunpowder is best bored from its flat surface by means of a large auger, (fig. 129), so that the bore-hole may go down to the junction of the roots. In case the tree is rotten at the heart, the boring must be made from one of the sides. The charge should consist of 1½, 3 or 4½ ozs. of blasting-powder, and a fuse should be introduced, or some other arrangement made for firing the blast. Fig. 130 shows a simple detonating apparatus, the ring (*a*) being for the insertion of a handle for screwing it into the bore-hole, whilst (*b*) is a simple trigger for striking the cap. Urich improved matters further by using an apparatus with a needle for firing the cap, which was placed on the top of the powder, as shewn in figs. 131, 132, the former giving its external form, and the latter a section through its axis. The apparatus has a bore sufficient for working of the needle (*m o*). It is closed by a screw-lid (*b*) in which the cap (*n*) is placed. In order to prepare the apparatus for firing, the needle is raised by means of the ring (*m*), and a steel pin is placed in the aperture (*d*). The lid (*b*) is then removed, and screwed on again after a cap has been inserted. The charge is fired on the removal of the pin by means of a long cord, the needle being driven down on to the cap by a strong spiral spring placed above the ledge (*m*). The advantage of this apparatus consists in the fact that it is not necessary to fill it with powder, but a cap only is required, and the firing of the charge follows immediately on the release of the needle which can be done from a distance with perfect safety, whilst no tamping is required for the blast, the strong apparatus screwed into the bore-hole serving instead; the results are excellent, the largest stumps being split into two or more pieces.

FIG. 129.

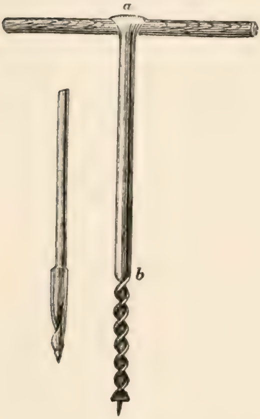
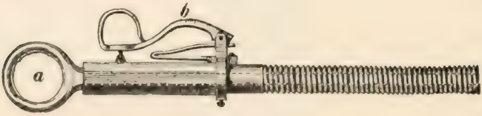


FIG. 130.



Whenever only a fuse is used, after less than half the powder has been poured into the bore-hole, the fuse, made of tarred yarn surrounding a thin column of powder, is inserted, and then the rest of the powder. The remainder of the bore-hole is then filled with earth or clay as a **tamping**, and firmly rammed-down.

Fig. 131.

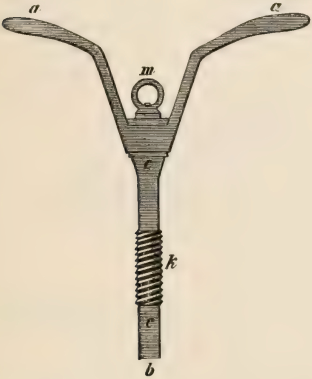
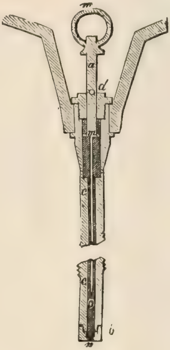


Fig. 132.



The portion of the fuse 4–6 inches long, which protrudes beyond the hole, is lighted with a match, and in 1–2 minutes the explosion follows.

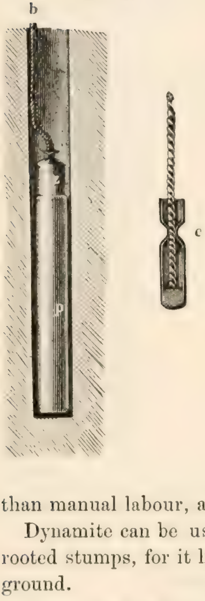
iii. *Blasting Stumps by Dynamite.*

Dynamite is a more powerful explosive than gunpowder, and is obtainable in cartridges, resembling brown stearine candles encased in thick paper. It becomes hard at temperatures of 45° to 50° Fah., and cannot be heated above 140° Fah. without danger. It will not explode, unless it be at least as soft as wax, and must therefore be slightly warmed during winter.

According to the size of the stump 1·7–2 grams (1–1·12 drams) of dynamite are required for every centimeter in the diameter of the stump, so that cartridges of 70 to 100 grams suffice for stumps of 0·50 to 0·70 meters in diameter [*i.e.*, 2½ to 3½ ounces for diameters of 1 foot 8 inches to 2 feet 3 inches.—Tr.], provided the wood is not too difficult to split.

The dynamite-cartridge (p) in fig. 133, is then placed in the bore-hole, which should be of suitable bore to admit it, and rammed home with a wooden ram-rod. A smaller cartridge (z) is used in connection with a fuse for firing the charge, the end of the fuse being placed on the soft mass of dynamite of this cartridge, and tied firmly above it in the paper covering of the latter. This firing-cartridge and fuse is then let down on to the blasting cartridge in the bore-hole. The vacant space in the bore-hole is then tamped with earth and the fuse lighted.

Fig. 133.



Whilst blasting with powder frequently only cracks the stump, by the use of dynamite it may be torn into several pieces.

As regards the cost and saving of labour by blasting the stump, various estimates representing from 30 to 50 per cent. labour saved have been made; for oak-stumps the cost is estimated at 6*d.* per stacked cubic meter cheaper than manual labour, and for Scotch-pine at 3*d.* more.

Dynamite can be used with advantage only on completely uprooted stumps, for it has scarcely any effect on those still in the ground.

Owing to its highly explosive nature, dynamite will not be much used for blasting stumps in forests, at any rate during winter; also on account of its high price and because it is a strong poison.

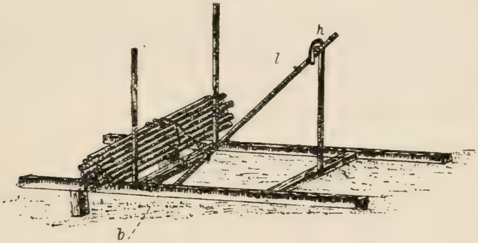
The use of blasting powder can, however, be strongly recommended for this purpose wherever the price of labour is high, and stumps have to be split.

(f) Preparation of Faggots.

Wherever twigs and branches are in demand for fuel, they are cut into lengths with the bill-hook, and bound into **faggots**, or **bavins**, by means of one or two **withes** or **binders**.

[Fernandez* gives a simple frame for faggot-binding as shewn in fig. 134. The lever (l), the lower end of which rests against the bar (b) is drawn towards the operator and hitched into the hook (h), thus tightening the chain over the bundle of sticks. The withes can now be tied and the pressure on the faggot released by unhitching the lever; the length of the chain, which can be varied, regulates the size of the faggot.—Tr.]

Fig. 134.



Faggot-binder's Press.

In other cases, small branchwood may be simply carried to the nearest roadside, and stacked in heaps between stakes.

Faggots should be made in whatever dimensions the public prefer. In country districts usually long thick faggots are in demand; near towns they are preferred when not exceeding 80 pounds in weight, and may be 1½ feet long, and 2¼ feet in girth, five smaller ones being bound-together to make a faggot.

The best withes are slender oak coppice-shoots, but hazel, sallow and birch, &c., will serve the purpose. These withes are freed from all side-shoots, and when freshly cut, or steeped in water, are placed on a fire to make them pliable, and then twisted like ropes into a loop at the thin end, through which the thick end is drawn when they are fastened round the faggot.

4. *Removal of Wood previous to Conversion.*

It has been hitherto presupposed that the conversion of the felled wood takes place on the felling-area near the stumps of the felled trees, and this is generally the case.

There are, however, circumstances in which it is necessary to remove the wood from the felling-area, or at any rate away from the stumps of the felled trees, before it is converted;—as in a young crop, during the final stage of natural regeneration; under a shelter-wood, in selection-fellings, cleanings and thinnings. Splitting firewood and conversion of the easily transportable poles and saplings may then be effected on neighbouring blanks, roadsides, etc.

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* Utilization of Forests, p. 108.

Wherever the firewood before being stacked has to undergo a further transport by water, sledge-roads or slides, it is advisable to convert it into short butts, and to split these up only after they have been transported to a depot.

5. *Occasional Non-conversion of Firewood.*

Owing to the present greatly reduced price of firewood, foresters are often obliged to give up converting it in the regular way just described. Wood yielding only round billets and faggots, especially from extensive thinnings, may then be simply carried unshortened, including the crowns, to the nearest roadside, and stacked between stakes.

There are districts where there is absolutely no demand for small poles, saplings, and branch-wood, as in many Alpine forests, or in districts containing many private and communal forests.

6. *General Rules regarding Conversion.*

Forest managers should bear in mind the following rules regarding conversion of timber and firewood:—

(a) The most urgent local demands of right-holders and contractors must be first satisfied, and the conversion of the remaining material effected from a strictly financial point of view, that is, with a thorough knowledge of the actual demands of the market.

(b) After carefully considering the demand, the wood should be converted so as to yield the highest possible net-value on deducting the cost of conversion. Hence, the mode of conversion is a purely local affair, and will vary greatly according to circumstances in different forest ranges.

(c) The conversion into any assortment should be regulated in quantity, so as not to glut the market, and to allow of the demands for other assortments being fully met. Forest managers should, therefore, be conversant with the state of the supply of different classes of material from other forests which compete with their own.

(d) The rarer and more valuable any assortments, the greater care must be bestowed on their conversion. This is especially the case with oak and large coniferous timber.

(e) Conversion of timber is often better effected when different classes of workmen are employed for the different works. Thus, in broad-leaved forests the work commences with the felling and conversion of the large timber trees, and after all the best timber is ready, what is left is converted into firewood and other inferior assortments. In coniferous forests it is often customary and advisable first to prepare the various cloven wares, such as shingles, staves, &c., then the butts for sawmills and the logs, and finally the firewood.

(f) The forest manager should always ascertain the wishes of timber-merchants, manufacturers and craftsmen of the neighbourhood, and they may be encouraged to visit the felling-area for this purpose, but he should be on his guard lest by following the advice of any of them competition for the produce may be reduced.

(g) Although it is justifiable, when the prices of wood are low and wages high, to attempt only a very rough conversion of firewood, or abandon converting it altogether, yet this should never be done with valuable material. Any carelessness in its preparation will do more injury to the forest revenue than paying high wages for good work.

(h) It is usually advantageous in forests where petty delinquencies are frequent, for the manager to compete with the thieves by selling better and cheaper material than they do, such as hop-poles, bean- and pea-sticks, Christmas-trees, &c.

SECTION VI.—SORTING AND STACKING CONVERTED MATERIAL.

1. *General Account.*

The rough conversion of the felled trees must produce many pieces of the same class, but of different qualities, shapes and dimensions, especially among the timber where scarcely two pieces are identically alike. As every producer keeps his wares of different kinds and qualities apart, so each kind of converted forest material should be separately arranged. In this way only can it be possible to estimate the probable value of the results of the felling, and to expose the lots for the inspection of the different classes of purchasers. The real object of separating assortments of woods used by various industries and consumers, is to obtain the highest possible price for each assortment. The arrangement of the assortments into classes should, therefore, be made on the following principles:—

i. All pieces which are of different value, and fetch different prices, must be put in separate classes.

ii. The classes must always correspond to the demands of the locality.

iii. The separation into classes should depend on differences of species, size, shape, quality, and demands of the market, and these will be discussed in detail further on.

iv. This separation must not be too minute, or go too much into detail, so that there can be any doubt about the proper classification of any piece, or too much difficulty in calculating and registering the results of the felling. There is a considerable difference in this respect between valuable pieces of timber, and common sorts or firewood. In the former case, the manager can hardly go too far in subdividing the classes, and a difference of price exceeding ½*d.* per cubic foot should cause a different class of timber to be established.

A difference of value is, therefore, the chief reason for a difference in class of material.

2. *Detailed Account.*

(a) Species.

The species of tree has a great influence on the use to which the wood can be put. Timbers of different species should, therefore, be separated into classes, or at least species of equal value should be classed together. The same procedure should be adopted in the case of firewood, or where there are few of them all inferior kinds should be separated from those more valuable.

Of great importance in sorting felled material is the comparative abundance or rarity of any species. Thus, where valuable oakwood is abundant, the chief point to attend to will be to classify the oak-timber; in coniferous forests, the spruce or pine timber, and in beechwoods the beech-timber and the better classes of firewood.

(b) Dimensions.

Logs, butts, and poles will be classified according to their dimensions. As the value of a log or butt is not always directly proportional to its cubic contents, but to its length or thickness, and in the case of coniferous wood to the thickness of its smaller end, the pieces will be classified accordingly.

Such classes are formed according to differences of about 6 feet in length, and 2—4 inches in thickness. In the case of valuable timber, the classification according to thickness may go down to one centimeter. [Thus, in France, oak-timber increases in value at about one franc per cubic meter, for every additional centimeter in diameter over fifty centimeters.—Tr.] The less valuable the pieces, the rougher the classification.

Large billets always increase the solid contents of a pile of stacked firewood, so that firewood should also be classified according to dimensions.

(c) Shape.

Curved timber should be classed according to the degree of curvature for a certain length, or in kneed-timber for the angle at which the branch leaves the main piece.

In classifying other timbers, the chief points to which attention should be paid are ;—whether they are straight, bent in one plane, quite crooked, or contain burrs ; also, whether they are clean-grained, or have been merely trimmed free from many branches and are knotty.

In the case of firewood, also, straight billets of split or round stem-wood should be piled separately from crooked and knotty branch-wood.

(d) Quality.

Independently of its soundness, which is always presupposed in the case of timber, there is a great difference in quality depending on its grain. Thus, we have coarse-grained and fine-grained timber, timber with broad or narrow annual zones, with straight, twisted, or wavy fibre. Some stems are naturally smooth on the surface, others lumpy owing to occluded knots. All these circumstances affect the value of the pieces, and should be considered in sorting them.

In the case of firewood any unsound and broken pieces should be piled apart from the better wood, and as the age of the tree often influences the heating-power of the wood, young or very old wood may be separated from middle-aged wood.

It cannot be too often repeated that only sound wood should be classified as timber. Wood, in its present struggle against iron and other substitutes for it, can only win the day when it is sound and durable. This is especially the case where the wood has to be transported long distances, and is subject to indifferent treatment before it reaches the consumer.

(e) **Local Demand.**

In classifying the produce attention must always be paid to the local demand. Thus, in certain localities, custom may render it necessary to classify wood in a way which is quite uncalled for in other localities. Whilst, however, sufficiently conforming to custom in this respect, the manager should always attend to the chance of changes being gradually introduced in conformity with the demands of more distant markets than his own immediate surroundings.

3. *List of Wood-assortments.*

The following list gives all the common sub-divisions of the different classes of produce from the fellings.

A. LARGE TIMBER.

(a) *Logs.*

i. **Oakwood.**

1st class, logs over 20 inches in mid-diameter, and 30 feet in length, thoroughly sound, straight, fibre not twisted, with fine bark and easily split.

2nd class, logs over 18 inches in mid-diameter and 30 feet long, thoroughly sound, being somewhat bent, coarse-barked and not very fissile.

3rd class, logs over 14 inches mid-diameter and 20 feet in length, with some defects which cause waste in sawing.

4th class, logs over 12 inches mid-diameter and 20 feet long, fairly sound, straight-grained and fissile.

5th class, logs over 10 inches mid-diameter and 20 feet long, fairly straight, but with some knots and defects.

6th class, logs over 6 inches mid-diameter and 20 feet long, fairly sound; also defective logs of larger dimensions and logs from dead trees.

In the first four classes of this group are included the 1st and 2nd rate shipbuilding timber; the best wood for staves, planks and building-timber. The two last classes include inferior wood for staves, building-material, ship-knees, pit-wood, small planking, &c.

ii. Coniferous Timber.

After rejecting wood from diseased trees and setting apart the finest ringed and straightest grained wood, the outer shape and the dimensions of the timber form the chief guide for classifying coniferous wood. As regards dimensions, the logs may be classified according to the mid-diameter, or to the small-end diameter. In no other case has the latter so important a bearing on the value of the timber, as in coniferous logs, and accordingly in many districts of North and South Germany the classification is so arranged. The mere volume of the logs is a bad index of their comparative value.

Considering the usual sizes of logs, a separation into five or six classes will suffice, in the following manner:—

1st class, logs thoroughly free from knots, smooth, straight, fine-ringed, straight-grained and fissile, over 60 feet long and at least 11 inches across at top.

2nd class, logs of similar quality and length, and over 9 inches across at top.

3rd class, logs of similar quality over 50 feet long, and over 7 inches across at top; also larger logs of inferior quality.

4th class, logs of good outward appearance over 45 feet long, and over 6 inches across at top.

5th class, logs over 40 feet long and 5 inches across at top.

6th class, logs over 30 feet long and 4 inches across at top.

Wherever the classification is by the mid-diameter—

I. and II. classes, logs of 14 inches and more.
III. class, logs of 10—14 inches.
IV. class, logs of 8—10 inches.
V. class, logs under 8 inches.

All measurements are supposed to be taken without bark.

The first two classes comprise timber for masts, booms, mill-wheel axles, and the best building-timber.

The other classes comprise ordinary or inferior building-timber, rafters, fencing rails and pit-props. Wood for paper-pulp, which is often taken in lengths of 25—50 feet and longer, belongs to the last three classes.

iii. Remaining Species.

Broad-leaved trees, other than oak, do not yield much marketable timber; the exceptions to this rule are elm, ash, alder and aspen. [Willow and sycamore are valuable in Britain.—Tr.] In many cases each of these woods may be separately classified, and the others classed together. Wherever any of these timbers are of special value, they should be classed separately.

(b) *Butts.*

i. Oak.

1st class, 12—20 long and over 20 inches in diameter. Good quality.

2nd class, 16—20 inches in diameter.

3rd class, 12—16 inches in diameter.

4th class, 8—12 inches in diameter.

5th class, butts exceeding 8 inches in diameter, but of inferior quality. They must, however, be good enough for railway sleepers and for sawn timber.

6th class, butts exceeding 8 inches in diameter, but too inferior to come into class 5.

The above timber is for sawing, staves, cabinet-making, wheelwright's work, gate-posts, &c.

ii. Coniferous Wood.

1st class, butts of best quality for musical instruments, shingles, and other split ware.

2nd class, butts of 14 inches mid-diameter and over; straight grained.

3rd class, butts of 10—14 inches mid-diameter.

4th class, butts less than 10 inches mid-diameter.

5th class, butts of inferior quality and of various sizes.

The wood in these classes is chiefly intended for sawmills to be converted into planks, boards and scantling. The wood must be classed according to species, and occasionally more classes than those here given will be required.

As regards length, it is generally constant for the same locality, according to the custom of the sawmills or floating trade. The timber-trade prefers lengths of 10, 11, 12, 14, and 18 feet. The smallest class is usually used for water-pipes.

iii. Remaining Species.

Here according to the quantity of timber available, and the demand, a separation into classes is advisable. Three classes for each kind will suffice. Among broad-leaved trees, beech ranks next to oak in importance, and most requires separate classification.

Frequently logs and butts are classed-together, and then six to eight classes are required for oakwood and four to six for conifers.

B. POLES.

In this group poles used for building or other industrial purposes come first, and then those used in agriculture. There is great variety in different districts as regards their dimensions: the following list only gives the more important classes, most of which, and especially the larger sizes, may be sub-divided into two, three, or even four sub-classes.

1. Building- and scaffolding-poles, always coniferous, 30—50 feet long and more, 100 pieces containing 200—300 cubic feet (6—8 cubic meters).
2. Telegraph-posts, 25—30 feet long, 6 inches across at top.
3. Ladder-wood, 20—40 feet long, 100 pieces containing 175—200 cubic feet.
4. Cart and agricultural implement poles, of both broad-leaved and coniferous wood, 100 pieces containing 100—175 cubic feet.
5. Hop-poles, coniferous [except sweet chestnut—TR.], 15—30 feet long, 2½—5 inches in diameter at 4 feet from the base, generally sub-divided into four or five classes. One hundred pieces contain 125, 80, 60, 35, 20 cubic feet.
6. Poles for fastening logs into rafts.
7. Tree-props of different species.
8. Tree-stakes of different species.
9. Poles used for making hooping for casks.
10. Crate-wood and hurdle-stakes.

11. Fascine-stakes and hurdle-rails.
12. Bean-sticks, 10—15 feet long.
13. Fencing-stakes, 10—15 feet long.
14. Hedge-stakes [also walking-sticks and sticks for umbrellas. —Tr.]

C. Stacked Wood for Splitting.

As regards species; oak, sweet chestnut, alder and ash should be placed separately, also conifers.

Further separation into two or three classes, according to dimensions and fissibility, is also necessary. This group must always consist of sound wood. Stacked oakwood is, in the Palatinate, divided into two groups, stave-wood and wood for vine-props, the former into four, and the latter into two classes; wood of other species and coniferous wood are each divided into three classes.

The round pieces of stacked timber are divided according to species into two classes of different dimensions. They are used for vine-props, pit-props, and in lengths of 5—6 feet for the manufacture of paper-pulp.

D. Brushwood.

1. Withes.
2. Osiers for basket-making.
3. Wood for brooms and pea-sticks.
4. Wood for fascines.
5. Thatching material.
6. Christmas-trees.

E. Firewood.

1. Split billets, thoroughly sound wood, sub-divided into two classes according to size.
2. Crooked billets, sound but knotty.
3. Broken wood. Unsound split billets sub-divided into two classes according to the degree of unsoundness.
4. Round billets from stems.
5. Round billets from branches.
6. Peeled round billets from oak-coppice grown for tan.
7. Rootwood. This may be divided into two classes, when it sells well.

8. Large unsplit pieces.
9. Small split billets fastened with withes (Fr. *cotrêt*).
10. Faggots of larger wood from thinnings without twigs, under 2½ inches in diameter.
11. Branch-faggots.
12. Faggots of thorns, &c., from cleanings.
13. Heaped-up faggot wood.
14. Bark for fuel. The bark of silver-fir and spruce, when it is not required for tanning, is often stacked and sold for fuel. The bark rolls-up when thoroughly dried, and becomes less bulky.

SECTION VII.—CLEARING THE FELLING-AREA.

1. *Explanation of the Term.*

The felled and converted material of different kinds, which during the process of conversion lies scattered over the felling-area, must be sorted and collected in a **temporary forest depot.** This is situated within the felling-area, in a valley or on a road leading from one, at the top of a timber-slide or sledge-road, or on the banks of a stream down which it is proposed to float the material. In no case, however, should the forest depot be so far removed from the felling-area that the material cannot be transported there by the regular woodcutters with the help of simple means of transport.

Clearing the felling-area, therefore, means removing the material by dragging, carrying, sliding, or sledging to a convenient forest depot either within the felling-area or not too remote from it.

Whenever the material is to be removed to a **permanent depot** near the place of consumption or a railway-station, by means of more or less permanent means of communication, such as roads, slides, forest-tramways, streams, &c., all the measures required to effect its removal come under the head of **wood-transport.** Clearing a felling-area and transport cannot however be distinctly separated, and sometimes they are both carried on simultaneously by means of the same gang of woodcutters.

2. *Purpose of the Clearance.*

The wood is generally removed from the felling-area before selling it for different reasons: first, to facilitate the estimation of the yield of the felling in quantity and quality; then, for sylvicultural reasons, and finally, to improve the forest revenue.

The first of these objects is obvious, and wherever the estimation of the yield depends on the clearance, that is clearly a part of the classification of the timber which has been already described (p. 268). The wood must be stacked in assortments in the forest depot, and the woodcutter who assists in removing it from the felling-area must understand the local classification of the material.

It is also evident that the removal of the material must act beneficially on the growing-stock, and that the preservation of the latter is much better secured when the forest manager controls the clearance of the felling-area, than when the indifferent or careless wood-merchant deals with it, and is therefore admitted into all parts of the forest. Besides, in many conditions of the standing-crop it is essential that the converted material, which must remain in the forest until it is removed by the purchaser, should without delay be withdrawn from the felling-area, so that the latter may be left free and undisturbed for sylvicultural operations. This is above all necessary in the case of coppice and coppice-with-standards, and also in natural regeneration-fellings in high forest.

The collection of the produce of a felling in depots accessible to ordinary carts, and which offer no difficulty of access to timber merchants, must act beneficially on the prices and increase the forest revenue. Experience clearly proves that money carefully spent in this way will amply repay itself, and even if there were no other objection to the clearance being effected by the purchaser, it is evident that the forest manager can do the work cheaper than the individual purchasers of different lots.

3. *Choice of a Forest Depot.*

In order to secure the above objects as thoroughly as possible, the proper choice of an area to serve as a forest depot is highly important. Every forest depot should be so situated as to be within easy reach of the timber-purchasers' carts, or other modes of transport, and so that the neighbouring woods may be liable to the least possible amount of injury in both the clearance and transport of the material; it must also be in an open, airy or at least dry position, and should offer sufficient room for the different classes of material to be arranged conveniently for inspection by intending purchasers and by the forest staff. Wherever the logs have been barked, the depot should also be shady, so that cracking may be avoided.

In plains, or moderately low mountain-ranges, the material is usually brought to the nearest road, or where this is not broad enough, into the forest bordering the road, including the ditches. Blanks on the felling-area, or, in the clear-cutting system the felling-area itself, may be used as a depot, if there is no immediate necessity for restocking them.

In higher mountain-ranges all the material from a felling-area must be brought down into the valleys, to the top of a slide, or to the banks of a stream. This is usually done whilst the timber-work is proceeding.

The depot should be dry and exposed to the air. This, however, is not always attainable; but the wood should not in any case be left lying in damp hollows, or other places which retard its drying. Wherever great numbers of trees are felled yearly, it is in the interest of the forest-owner to set-aside permanent timber depots for the reception of the material from felling-areas, and to place the logs on supports keeping them from contact with the damp ground.

4. *Material to be Removed.*

In general, all wood should be removed from the felling-area, the sale of which would at least cover the cost of removal, when only the simple means at the disposal of the woodcutters are used.

All firewood and the smaller kinds of agricultural wood should always be removed before sale; whether, or not, this should be the case with the larger logs and butts depends chiefly on the nature of the ground. If the felling-area is nearly level, it is easy for the purchasers' carts to come up to the stumps of the felled trees to load and convey the heavy pieces of timber directly to their destination. If, however, the felling-area is on a slope, skilful woodcutters will find no difficulty in removing the heaviest logs down to the valley below; in such places it is indeed necessary for them to do so, for carts cannot then leave the roads, and the purchaser of the timber must not be allowed to slide the logs downhill to his carts. On sloping ground, therefore, all large timber is removed by the woodcutters from the felling-area. Where there is only a gentle slope, the removal of the timber from the felling-area will depend on the amount of protection necessary for the forest crop. In many such cases, it is sufficient to remove the timber to the nearest cart-track passing through the felling-area.

The mode of re-stocking the area to be adopted will also influence the matter. If the area of a clear-felling is to be immediately re-stocked, all the wood on it must be removed. In the case of natural regeneration, there are usually blanks in the felling-area on which the heaviest timber may be placed.

Wherever the purchaser undertakes to fashion the wood in the forest, as in the making of sabots, spokes, staves and other cloven ware, the worksheds should, if possible, be kept outside the felling-area; the granting of the permit to prepare the wood should also depend on the acceptance by the purchaser of certain suitable sites for his work, provided such sites are available.

5. *Modes of Clearance.*

The felling-area may be cleared in different ways, which are more or less consonant with forest protection; such as carrying, sliding, dragging, sledging, letting-down by ropes, using timber-chutes and rolling downhill.

(a) **Careful Methods of Clearing a Felling-area.**

i. *Carrying.*

Carrying is chiefly done by men, seldom by beasts, and is confined to the smaller classes of material, such as firewood, poles, branchwood and cloven-ware.

As carrying by men is very laborious and expensive, it is done for short distances only, especially when wood has to be removed from young growth with the least possible amount of damage to the latter, or has to be taken a short distance uphill to a road; also on very rocky ground, where no other means of transport is practicable. The woodcutter either carries the wood on his shoulder or piled on a frame on his back, or it is carried on a litter supported by two people. Logs and poles may be carried on the shoulders of several people [or suspended from rods resting on their shoulders as they walk in pairs.—Tr.]. In natural reproduction-areas, especially during the final stage in spruce or silver-fir woods, all branchwood should be carried and not dragged from off the felling-area, as the latter plan does much damage to the young growth and predisposes it to attacks of weevils.

ii. *Removing wood on Wheeled Conveyances.*

This is always a careful method of clearing a felling-area, but can be employed only where the ground is fairly level. The ordinary wheel-barrow may be thus used, to which a rope may be attached to economise strength in pulling. Horses or bullocks may also be used on fairly level ground, with the front or back pair of wheels of a timber cart. In this case the log is hung under the axle of the wheels, and this is the best method available for removing timber from young growth without injuring it. The use of portable railways is also a method as good, if not better, than the above. [A French method of raising logs on to carts is shewn on p. 535.—Tr.]

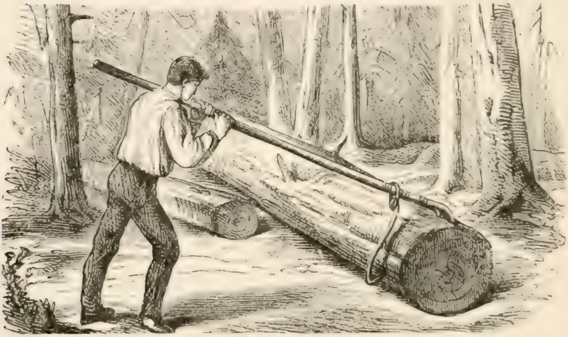
In order to further the transport, sufficiently wide cart-tracks or paths may be cleared, which are specially advisable if young growth is to be traversed. In any case this method is far preferable to carelessly dragging the timber along the ground.

iii. *Dragging or Sliding along the Ground.*

In this method either men or beasts may be employed. Various implements are used by the workmen to expedite matters, such as the *krempe* (fig. 137), or the implement shown in fig. 136, resembling a boat-hook, and also used in floating timber, or the strong **hook-lever** with hook and ring (fig. 138), or ordinary levers. In the case of beasts dragging the logs, chains are used, which may be fastened to the logs by grappling-irons (fig. 139), or by means of the slip (figs. 140, 141), or the short sledge (fig. 163).

Before a log can be dragged or slid it must generally be turned over, or rolled into the dragging-track; for this the hook-lever may be used as shown in fig. 135. To bring a log parallel to the dragging-track, it generally suffices to place a roller under its centre of gravity, when it can easily be turned in any required direction.

FIG. 135.



If a log is to be slid down by men, which can evidently only be done if the ground is sufficiently steep, it is brought into the sliding-track with its butt-end downwards, and then guided with the krempe at its butt, as it is forced to slide downhill by levers. The workmen who accompany it downhill release the log should it stick against any obstacle, and bring it down to the nearest export-road, or to level ground.

When beasts are used to drag the logs, such as horses, bullocks, [in India, buffaloes and elephants.—TR.] the ground must be level or only slightly inclined. The log is then held firmly, as in the Alps, by the grappling-iron, or a hole is cut in the butt of the log to which the dragging-chain is fastened. If the ground is covered with snow, the logs are simply dragged along over it, or are fastened to the front wheels of a timber-cart, or to a sledge. In any case much labour is saved by slightly

Fig. 136.

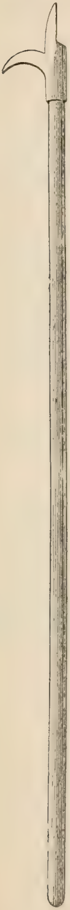


Fig. 137.

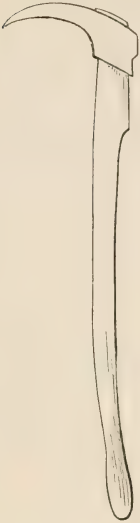


Fig. 138.

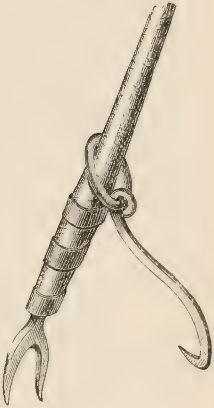


Fig. 139.

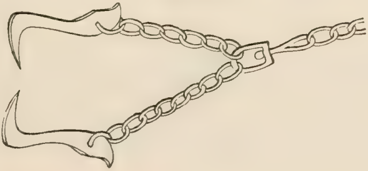


Fig. 140.

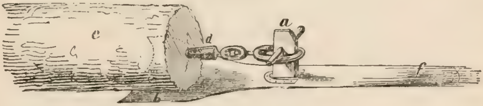
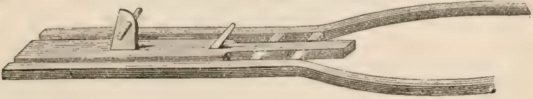


Fig. 141.



raising the butt-end of the log from the ground, as shown in fig. 140 for two beasts, or fig. 141 for one.

In most forests, sliding or dragging are the usual methods employed for clearing the felling-area; on slopes by men, and on fairly level ground by animals.

In the case of reproduction-areas, and especially those in coniferous forests, dragging should be done only with great care, and when there is sufficient snow on the ground. Dragging injures young plants more than any other method, and greatly exposes young conifers to attacks of weevils. It must, however, often be employed even when the ground is free from snow, but in such cases it is not sufficient to slide or drag the logs along cleared tracks; a pair of high wheels should also be used if the ground is not too steep. Logs should always be rounded at their butts when dragged or slid, as then they do less damage. A log passing through young growth should never be allowed to roll.

Rollers or large split billets of wood may be placed in the track, on which the log slides or is dragged; in this way some protection is afforded to the young growth.

When the ground is not stocked with young growth, there can be no objections to sliding or dragging timber from the felling-area.

iv. *Sledging.*

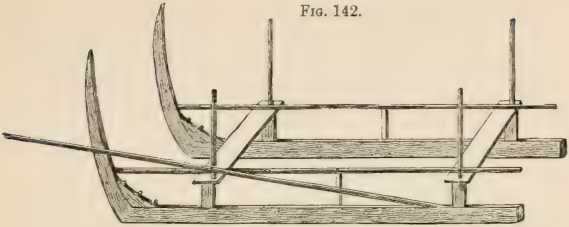
Sledges may be used for clearing the felling-area, and then on frozen ground or temporary sledge-roads, as distinguished from permanent sledge-roads, which will be described under wood-transport.

(*a*) **Construction of sledges.**—The mode of construction of ordinary wood-sledges may be seen from the annexed figures, different forms being used in various European countries and districts, but it has not yet been decided which is the best form to adopt under various circumstances.

[Two forms of sledge are in use in the N. W. Himalayas for transport of railway-sleepers and firewood, and have proved very useful. As the oak runners of these sledges become worn, soles also of oak are applied to them.—Tr.]

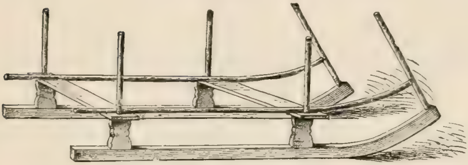
The requisites for a good sledge are lightness, strength, and dimensions allowing for a load which one man can transport.

FIG. 142.



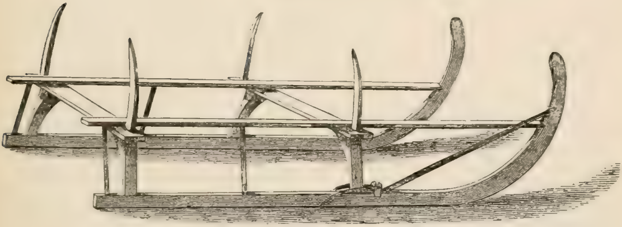
Murgthal Black Forest Sledge.

FIG. 143.



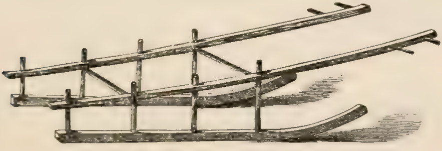
Middle Rhine-Valley Sledge.

FIG. 144.



Bavarian and South-Bohemian Sledge for butts 10–15 feet long.

FIG. 145.*



Southern Black Forest Sledge.

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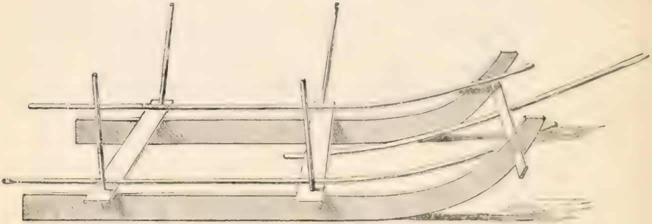
[*] Hess recommends the sledge shewn in fig, 145 on account of its lightness and simplicity, and because by pressing on its runners in front, it can be easily checked in speed.

(*β*) **Sledging-tracks.**—Wherever sledges are used for the removal of wood, a serviceable track must be made, which differs according as the sledging is done in summer or winter.

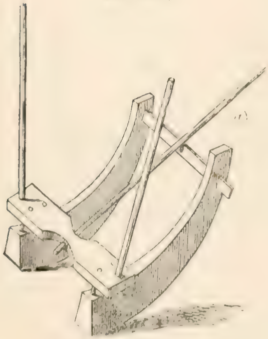
FIG. 146.*



Moravian Sledge.

For winter-sledging on fairly level frozen ground slightly covered with snow, a path is soon got ready after removing a few obstacles. On slopes, the case is similar, provided there are no holes, ravines or slight eminences in the way. Ravines and holes may be filled with branches or faggots, or billets of firewood may be piled up in them till they are filled.

FIG. 147.†



Moravian short sledge.

The track is then covered with snow, over which the sledge passes; this may be necessary where the wind has blown away the snow, whilst in other cases, it may have drifted too deeply, and part of it require removal. In many districts, woodcutters show considerable ingenuity in constructing temporary sledge-roads. Once the rest of the wood has been removed, the billets on the road are lifted and brought down on sledges.

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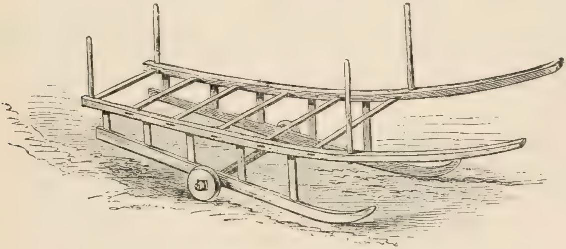
* In this sledge, the load rests distinctly on the runners, and its construction is very simple.

† In the short sledge (fig. 147) firewood is placed between the vertical arms and the shaft (*a*).

Whenever the snow is deep, the track must be beaten or trodden down. Where the snow on the felling-area is over two feet deep, the removal of the wood must be suspended, for it costs too much time and trouble to hunt for the pieces, and many of them would be overlooked. A winter with little snow is, however, worse than deep snow, for much time is then spent in placing snow on the bare parts of the track, or in preparing an ice-path. Until some snow has fallen, the work of clearing the felling-area must often be suspended.

Fig. 148.*



Barrow-sledge.

During summer, sledging can only be done on sloping ground, and even then is not always practicable ; for on slopes which are otherwise suitable, a sledge-track can often be made only with excessive trouble. This is often the case on rocky ground, or where the soil is deep. On slopes, however, which are covered with dead needles, or moss and herbage, sledges may run freely, especially over silver-fir and Scotch-pine branches, spruce being not so suitable. If then any hollows in the track are filled with billets and covered with branches and litter, or a kind of tramway made with round billets over the more difficult ground, sledging may be effected with great saving of labour, and is consistent with the protection of the young growth. It is, however, only practicable for short distances.

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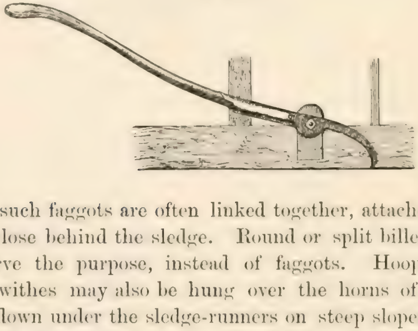
* The barrow-sledge (fig. 148), is much used in the Upper Schwarzwald, either on snow, or along cart-roads. It is, however, chiefly used on specially prepared paths.

(γ) **The operation of sledging.**—In all sledging operations, the workman stands in front between the horns of the sledge, which he holds in both hands, so as to draw the sledge or stop its too rapid progress.

Wherever the ground is even, or only slightly inclined, the sledge must be dragged, and the greater the angle of inclination, the less this is necessary; if then the track be smooth, with a gradient of 1 in 20 (5 per cent.), the workman has usually only to guide the sledge. As the gradient increases, he has to hold the sledge back; with gradients from 1 in 20 to 1 in 10 (6 to 10 per cent.), a man can do this without much difficulty, but with steeper gradients brakes must be used. Thus on steep inclines, the workmen have iron spikes attached to their boots to give them a good hold on the ground.

Brakes may consist of bundles of faggots in which stones are placed which are dragged after the sledge by an iron chain.

Fig. 149.



Several such faggots are often linked together, attached by short chains close behind the sledge. Round or split billets of wood may serve the purpose, instead of faggots. Hoops made of twisted withes may also be hung over the horns of the sledge and let down under the sledge-runners on steep slopes, and thus cause a great increase of friction. The iron hook and lever (fig. 149) is also used in many Alpine sledges as a break. In Moravia, the very small sledges (fig. 147) support only a small part of the load taken down at once; the rest is fastened in bundles and dragged behind the sledge, so as to act as a brake. As the track varies in steepness, parts of the load have occasionally to be left behind. The man takes what he can to the nearest steep part of the track, and then returns for the rest, and goes on with the whole load till he comes to another place where the gradient is insufficient, and some of it has to be left behind. Such a mode of sledging is most suitable with gradients from 1 in 4, to 1 in 3, (25–30 per cent.).

It is evident that besides using some form of brake, the workman must also use his own strength and press his spiked boots into the track at steep places.

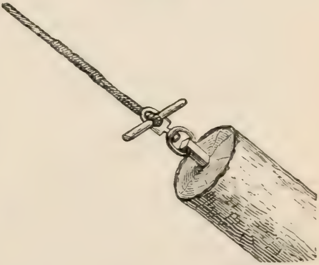
(δ) **Sledging without a regular track.**—Sledging, except on sledge-tracks, is generally confined to the transport of fuel or charcoal-wood. This is either split and piled transversely between the sledge-uprights, or if brought down in round pieces often of double the length of the billets, these are placed lengthways along the sledge in a pyramidal pile, and fastened to the sledge by short ropes or thin chains.

v. *Sliding Logs by means of Ropes.*

Thick ropes, 50–100 feet long and 1½–2 inches thick, are used for sliding logs down sufficiently steep inclines.

The method of attaching rope to the log is shown in fig. 150, or a hook may be attached to the rope and inserted into a hole cut in the butt-end of the log. According to the position of the log on the ground, it may be let down with its butt-end or smaller end first. After the rope has been attached to the log, it is wound once or several times, according to the weight of the log and the gradient of the ground, round the stem of a neighbouring tree or stump, and let down by gradually loosening the rope. It is accompanied by 1 to 3 men, who guide it past obstacles, or stop it with the *krempe* (fig. 137) or lever (fig. 138) freed from the kanting-hook, and direct its course among the young growth. Once the length of the rope is run-out, the log is firmly held by the men by means of krempes, until the

FIG. 150.



rope has been wound round another tree, and the process is repeated until the log has reached its destination.

This method is largely employed in different parts of the Black Forest, where up to 10*d.* a cubic meter (35 cubic-feet) is paid for the removal of the logs; this expenditure is amply covered by the higher price thus secured for the timber.

[Care must be taken that the rope is not wound round valuable standard trees intended to remain for several years on the felling-area, as their bark is then damaged, and unsoundness may ensue.—Tr.]

(b) Injurious methods of clearing a Felling-area.

In the following methods of clearing a felling-area, the wood is no longer under the control of the workman, but is left to itself while it moves.

i. *Rolling wood from the Felling-area.*

This is a method of removal only permissible over unstocked areas, as in the Clear-cutting System with artificial reproduction. In such a case it is an expeditious method if the gradients are not too great. When the gradient is considerable, it becomes dangerous to human life. In spite of this danger, however, workmen prefer it to any other method.

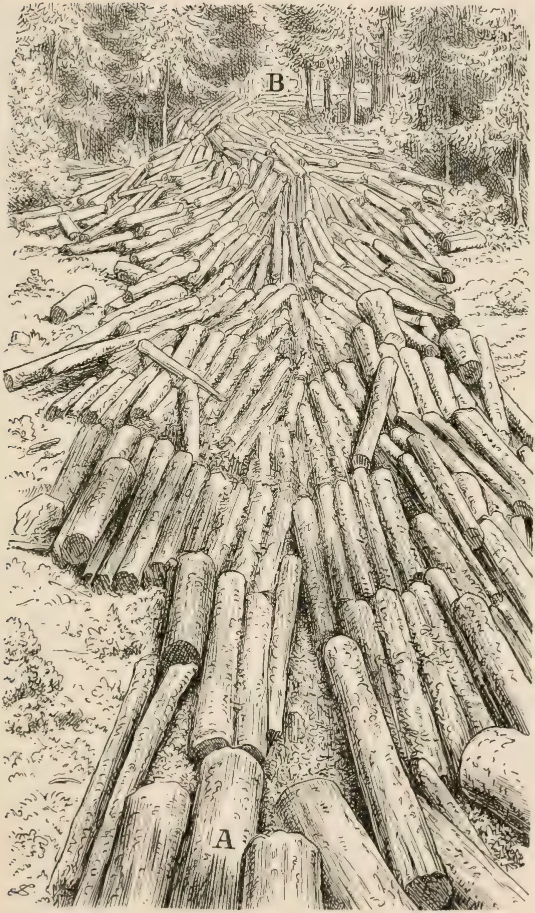
[It is largely employed in Assam in removing short Sal (*Shorea robusta*) and other butts from the forest to the river-side.—Tr.]

ii. *Throwing wood from the Felling-area.*

Another method employed for short round butts intended subsequently to be split into cordwood, is to throw them down hill topsy-turvey from terrace to terrace. A firm surface to the ground is necessary, such as snow with a hard frozen surface, on which the wood may slide or roll as well as turn over. It may also be done in wet weather, but deep snow greatly impedes the descent of the logs.

The krempe is usefully employed in setting the logs in motion. The practice can only be employed over unstocked areas. It is rendered more practicable when wood from the felling area is

FIG. 151.



piled on both sides of the line selected for the descent of the blocks, thus keeping them well together.

iii. *Sliding timber.*

This is the method of allowing logs and butts to slide down-hill by their own weight. Their butt-ends are rounded and turned down-hill. Any depressions in the hill-side are speedily filled with butts and logs, and the workmen try to keep these lying parallel to one another in the direction of the greatest slope, so as to assist the other logs in sliding over them.

This method is largely employed in the Austrian Alps, and in Franconia. Wherever on the hill-side the gradient of the slope is insufficient for any further shooting of the logs to be done, they are turned at right angles to their previous direction and rolled by means of the krempe to the next steep slope, where sliding can be recommenced. This method is illustrated in figs. 151, 152, the fall in either case being from the top of the diagram.

iv. *Dry timber Chutes.*

These are narrow ravines among mountains, with steep sides, and are barred by means of a horizontal log, behind which a number of short, round logs are collected and let loose down the ravine by cutting away one end of the bar. This method of removal is employed in the Alps, for short distances, where there are ravines suitable for the purpose, and other methods of removal are too difficult.

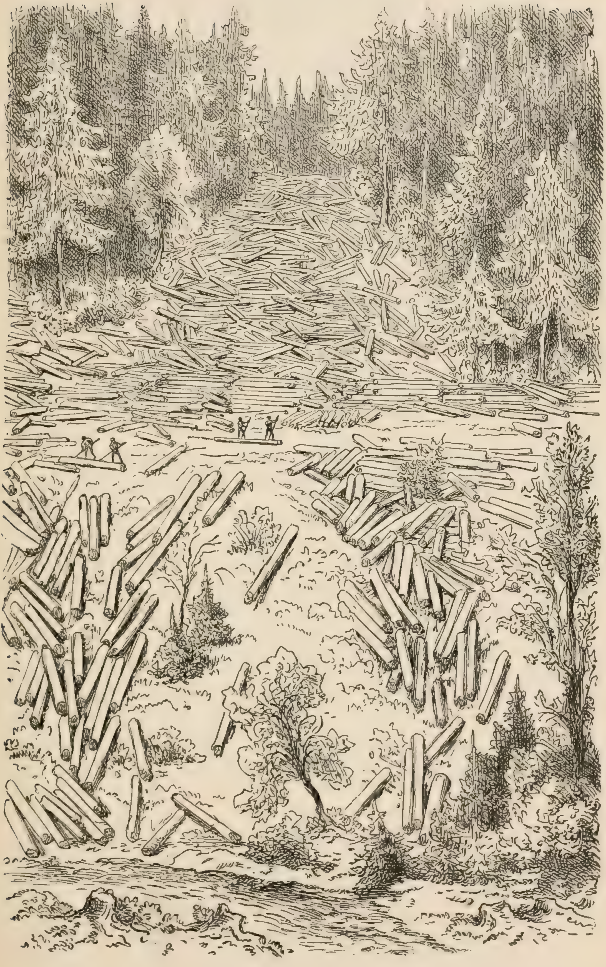
In some cases the bed of the ravine contains a mountain-torrent which may be temporarily dammed, until there is a sufficient head of water to carry the logs down, when the dam is released. This is termed a **wet timber chute.**

Evidently, wherever timber is left to fall downhill by its own weight, and without being under the control of the workmen, much breakage and loss of bulk by friction must ensue ; so that these methods will be adopted only where more careful methods are impracticable or too expensive.

6. *Season for Clearing the Felling-area.*

The season for clearing a felling-area depends on that of the felling, and on the mode of removal employed, as well as on the subsequent transport of the timber, and the available labour-force.

FIG. 152.



It is a general rule to clear a felling-area as soon as possible after the conversion of the felled material, and bring the latter into suitable places for its preservation and seasoning. This is especially urgent in coniferous forests, where there is much danger from beetles. Rapid removal of the material is also necessary on natural regeneration-areas, and other areas stocked with young growth. The mode of removal employed should also be considered, depending as it does chiefly on the configuration of the ground. In plains and low mountainous districts, there is no reason why the removal should not follow immediately on the conversion of the wood. In high mountain-districts, it is frequently necessary to await a fall of snow before clearing the felling-area, and all that can be done in summer is to convey the wood to the nearest valley, or road, and proceed further with it during winter.

It is evident that the clearance of regenerated areas demands the greatest care, especially when long logs are to be removed. The spring, just before the buds shoot, is then the best season, the young plants being less brittle than in winter, even with a moderate snow-covering. If, however, the snow is deep and firm, and it is possible to do the work, the clearance should be effected in winter.

The season of removal also depends on the subsequent transport of the timber. In plains, the duration of frost in winter greatly affects the transport. If the wood has to be floated or rafted to any distance, it is often necessary first to allow it to become thoroughly dry, especially where the streams are shallow. In such cases, 1½ years may elapse between the felling and the arrival of the wood at the saw-mills, which clearly involves great risk to the quality of the timber. In such cases the best logs should be speedily removed from the forest to airy forest-depots.

7. *General Rules.*

The following general rules apply to clearance of the felling-area :—

(a) All wood, the sale of which will repay the cost of removal, should be removed, and this may always be expected unless prices have gone down most abnormally.

(b) All wood lying in places inaccessible by carts, such as ravines, rocky ground, swamps, and steep slopes, should be removed. In the case of dead wood, clear cuttings, thinnings, &c., in flat or slightly hilly ground, the material is frequently left *in situ*, to be removed by carts, but even in such cases the collection of the wood by the proprietor often increases the forest revenue.

(c) Wherever there is a crop of young growth, as in all secondary and selection fellings, extraction of standards from younger wood and where trap-trees for beetles are felled, the wood should be at once removed from the felling-area.

If, in such cases, the heavier logs are not at once removed, as on fairly level ground, all the rest of the material and especially the firewood should be removed as soon as possible by workmen under the control of the forest manager.

The logs left on the felling-area should be raised above the ground on pieces of wood and removed as soon as possible by purchasers.

(d) The forest depot and the paths leading to it must be selected by the forest manager before commencing the felling, and all wood from the felling-area brought to the depot without delay. In mountainous districts, where there is scarcity of room, vacant places for stacking timber are provided by widening the roads leading downhill at suitable places.

(e) The method of removal of the wood to be adopted must be prescribed beforehand and adhered to as much as possible. All unsylvicultural methods should be avoided and employed only in high mountain-districts, where the timber cannot otherwise be removed.

Where the wood is thrown downhill, the timber should all be removed before the firewood, so that they may not become mixed together.

(f) The greatest care must be taken of the young growth when the wood is being removed, and tracks, along which this is permitted, should be selected beforehand by the manager. Great care must be taken not to injure the bark of standing trees during the removal of the wood, as this frequently causes unsoundness and greatly depreciates the future value of these trees.

On fairly level ground, if there is no snow, the heavier material should be removed, especially through young coniferous growth, by means of horses and a pair of wheels. On slopes, the groups of young growth should be surrounded by heaps of branches to protect them. Timber may be removed across natural regeneration-areas without any serious damage, but this is undesirable in the case of artificial plantations.

(g) The wood should be removed in assortments, and then stacked at the forest depot. Care should be taken to economise space in the latter, and that the piles of material on hillsides are stable. [In some cases terraces must be carefully made for locating the stacks.—Tr.] All small timber should be piled in hundreds or fifties, and butts and logs in lots of five, ten or more. Heavier pieces which would otherwise remain some time on damp ground should, as soon as possible, be raised on supports above the ground.

(h) Each party of woodcutters must remove and pile its own wood separately from that of other parties, in order to facilitate payment for the work.

(i) Removal from the felling-area and transport to the sale-depot are frequently done simultaneously; in such cases the work may be entrusted to a contractor under strict rules to prevent damage.

It often happens in the plains, in the case of clear-fellings, that great numbers of logs have to be removed, and this may sometimes be done best by means of contractors' horses, mules, or bullocks. In high mountain-regions removal and transport are generally done by contract [as in Indian fuel-forests.—Tr.]

Section VIII.—Sorting the Converted Material and Fixing the Sale Lots.

The first rough sorting of the material from the felling-area is done when the workmen bring the pieces to the forest depot, and this classification will hold for all the heavier pieces, logs, butts, &c., which cannot be moved about in the depot. The men must therefore take the greatest care to arrange these pieces properly, once for all. Pieces, however, which can easily be moved by the men may be somewhat more carefully arranged at the depot itself; this refers chiefly to firewood and small timber. Every kind of material is then arranged in small lots, which can be easily measured and their value estimated.

This arrangement should be commenced as soon as sufficient stuff has come down from the felling-area, and continued *pari passu* with the conversion and clearance of the latter, so that it may terminate immediately after the felling-area has been cleared.

The sale-lots may be either in **separate pieces**, by **numbers of pieces**, or in **stacked volumes.**

1. *Single Pieces forming a Lot.*

All large pieces, such as logs and butts, are measured separately, and even if several such pieces are sold together, the rule is to estimate the value of each piece separately.

In the case of broad-leaved timber, hardly any two logs or butts are alike, and each piece should be sold separately. Coniferous pieces, on the contrary, are far more regular in quality, form and dimensions, especially the butts intended for saw-mills; a moderate number of similar pieces may therefore be arranged in a lot. Places in which they are to be arranged should therefore be shown to the woodcutters before any wood has come down to the depot.

In forests subject to inundations, logs should be secured with cords or wire to posts driven into the ground.

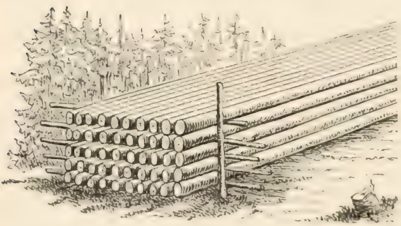
2. *A Number of Pieces forming a Lot.*

All inferior timber, such as poles, &c., which resemble one another sufficiently, should be placed in lots of 25, 50 or 100. A lot of hop-poles or bean-sticks of first or second quality is easily arranged, an average piece of each kind being selected to guide the workmen.

Assortments of small timber should therefore be arranged in the depot in classes and sub-classes. This work will be the more easily done if the woodcutters sort them carefully during the clearance of the felling-area. It is everywhere customary to place small poles and saplings in hundreds, and the larger kinds, and those for which there is only a moderate demand, such as scaffolding-poles, ladder-wood, cart-poles, &c., may be placed in fifties or quarter hundreds.

They should be placed with their thick ends towards the road between stakes driven into the ground. The smaller kinds—bean-sticks, hurdle-wood, &c.—may be fastened together in lots of 25. Poles may be conveniently arranged by tens, a small rod being placed under the thick ends of each ten poles, in order to facilitate removal (fig. 153).

FIG. 153.



3. *Stacked Wood.*

All firewood, and as a rule all branch-wood, cloven-wood, or fascines, should be measured by stacked volume, and therefore piled in regular stacks; a much more difficult matter than the simple one of piling poles, which must therefore be described in detail.

(a) **Shape and Size of the Stacks.**—The stacks of firewood, billets, &c., are usually rectangular parallelopipeds, of different dimensions in different countries; in Germany, Switzerland, Austria, France and Italy the unit is generally a stacked cubic meter (*Raummeter* in German, or *stère* in French*).

It is, however, usual, even when the wood is measured in stacked cubic meters, to place three or four stères of wood in a stack approaching in volume to the old customary measures; the usual number is then 3 stères, but 1 and 2 stères are sometimes employed. The normal length of the billets in a stack is 1 meter, but especially in the case of cloven timber this may be varied. The length of the pieces is considered as the **width** of the stack, and its other dimensions are termed **length** and **height.** Thus, for 1 meter of **width,** we have for

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* [In France, the ordinary cord 9 ft. × 3½ ft. × 2¾ ft. = 3 stères. (The French foot = 1 ft. 1⅛ in., English measure). In England, the cord is either 216 c. feet = 12′ × 6′ × 3′ and is then called a fathom and nearly = 6 stères, or 108 c. feet = 3 stères, or 72 c. feet = 2 stères, as in America.—TR.]

	Meters.	Meters.
4 stères	2·67 long	1·50 high
	2 ,,	2 ,,
3 ,,	3 ,,	1 ,,
	2 ,,	1·50 ,,
2 ,,	2 ,,	1 ,,
	1·6 ,,	1·25 ,,
1 ,,	1 ,,	1 ,,

[In the fuel supplied to the British army at Chakrāta in Northern India, the stacks are 21 feet long × 5½ feet high and 2 feet wide; this is supposed to contain 200 cubic feet, 1 foot in length and ½ foot in height being allowed for shrinkage.—Tr.]

The stacks should not be too high, especially on sloping ground and with coarse split roots or heavy wood, and the height should not usually exceed 5 feet; high stacks only increase labour, and are liable to fall.

The usual size of brushwood-faggots is, with the exception of fascines, of the same girth and length as an ordinary split billet.

(b) **Piling the Stacks.**—In selecting the site of a stack, damp places must be avoided, and a ridge is preferable, if available.

As a rule, two sufficiently long stakes are driven vertically into the ground at the same distance apart as the length of the stack. In order to hold the pile of wood firmly it is better to have at each end of the stack two stakes, which must be strong and driven by mallets deeply enough into holes made in the ground by crowbars. Opposite stakes may be tied by withes or strings, passing through the piled wood to prevent it from forcing them apart, or side-supports may be applied to the stakes.

On an incline the distance between the stakes must be measured horizontally and the top of the stack should be parallel to the incline. It is better not to substitute a standing tree for one pair of the stakes, as the roots will prevent there being a level base for the stack, and irregularities in the height of the latter may follow.

In stacking wood, the workman should pack it as closely as possible. The base of the stack is made by laying several pieces lengthwise on the ground on which the rest of the wood is piled transversely; this precaution should always be adopted where the wood has to remain for a long time on wet ground, otherwise the lowest billets may be forced into the ground and rot. On dry, firm soil, this arrangement may be dispensed with: the largest billets are then placed transversely, with their curved sides downwards, directly on the ground (fig. 154), and the stack is completed with wood of the same quality, the larger pieces being always piled first to ensure stability: at the same time, the men should pile the wood in such a way as to keep the top of the stack continually horizontal.

FIG. 154.

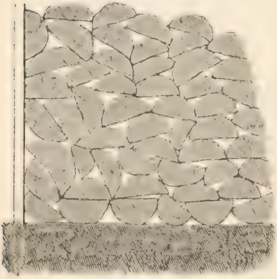
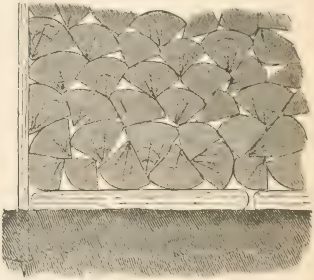


FIG. 155.



In order to pile the stacks closely, and also to protect the wood as much as possible from rain, it is better to place the curved sides of the billets above and their points downwards (figs. 154 and 155), except in the lowest row. The front surface of the stack should also be quite level and vertical, and as the billets are of different thickness at the two ends, they should be alternately placed with their thick and thin ends at either face of the stack. The first cord binding the stakes should be placed at a height of 1½ feet (half a meter), and the second at 3 to 4 feet (1 to 1¼ meters).

Stacking stump-wood is most difficult, as the shape of the pieces is so variable. Split pieces of small stumps are placed in the ordinary direction, but the larger pieces have to be arranged according to the skill of the operator, so as to fit in with the others. Spaces that cannot be otherwise stacked should be filled in with broken pieces and small roots, but round pieces should not be used for this purpose; a stack of stump-wood should contain nothing but pieces of stumps and roots.

When the workman has raised the stack to nearly its proper height, he should carefully measure it so that the proper height may be attained, but not exceeded. To ensure this, it is often necessary to finish the top of a stack of split billets with a layer of round ones.

Stacks should, if possible, be placed alongside one another in long connected rows. This economises space, and secures the stacks from being overturned. In case the firewood has to remain over winter in the forest, the long stacks are, if possible, placed in parallel rows, with intervals between them narrower than the length of the billets, and the topmost pieces are arranged to form a complete roof over all the stacks.

(c) **Shrinkage.**—As the green stacked wood shrinks while drying, and if not removed for some time will lose its bark, in many countries, such as Bavaria, Switzerland, &c., it has become customary to increase the height of the stacks, so as to allow for shrinkage. In Prussia and other German countries, this is done only when there is a long interval between the stacking and the sale of the firewood, but in Württemberg and Hesse no excess height is allowed.

This excess height is as follows in different countries:—

Prussia $\frac{1}{25}$th of the regular height.
Bavaria $\frac{1}{15}$th ,,
Switzerland $\frac{1}{20}$th ,,

Considering that the shrinkage of the billets does not depreciate the heating-power of the wood, and that its total amount varies greatly according to circumstances, such as the interval between stacking and sale, the species of wood, the position of the stack, the degree of splitting, &c., and that no excess is allowed for shrinkage in the case of timber, it is advisable not to allow for it in firewood except where legal rights to that effect have arisen. It has also been proved by Böhmerle* that there is scarcely any change after a year in the height of a stack of firewood, as warping counteracts the shrinkage, so that according to his experiments, its height decreases only by about an inch in a year.

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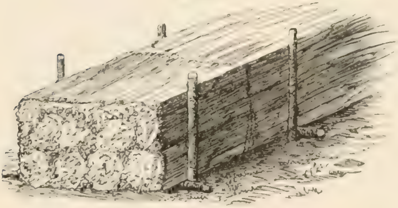
* Das waldtrockne Holz, Vienna. 1879.

(d) **Stacks of Cloven Timber.**—In stacking cloven timber, great care must be taken to separate the better kinds from inferior timber, and not to suffer any unsound or knotty wood in a stack. In the case of oakwood, all sound split pieces must be included in stacks of cloven timber, and oak-firewood stacks should not contain a single sound piece which can be classed as timber.

Deviations from this rule are justifiable only where there is no demand for inferior classes of cloven wood.

(e) **Stacking Faggots.**—Faggots are collected into piles each containing 25, or a multiple of 25 faggots. They are sometimes put horizontally, but keep much better standing, three faggots being laid in a pyramid and all the others placed leaning against them.

FIG. 156.



When faggots are not prepared, the branchwood is generally piled in heaps, and may be cut into equal lengths for this purpose. It is sometimes piled, as shown in fig. 156, and roughly tied in bundles to facilitate transport.

(f) **Special Men employed.**—Ordinary woodcutters are not allowed to stack firewood, as in their own interest they would make as much of it as possible. Special men are therefore employed, who are well known to the forest manager and thoroughly trustworthy. They should pile the wood prepared by each party of woodcutters separately, so that their earnings may be calculated.

3. *Protecting the Forest Depot.*

The supervision and guard over the material at the depot is greatly facilitated if it be arranged according to an easily recognized plan. It must be placed so that the purchasers' carts can approach each lot as nearly as possible. This is more easily attained when the conversion and sale of the timber precede that of the firewood, and the billets may then be stacked in long rows along the roads or rides, with the faggots behind them.

As a rule, the mode of arrangement of the depot depends chiefly on the area available, but the forest manager should always endeavour, like a trader, to secure a good display of his wares.

When the last firewood stack is ready, and the felling is thus completed, all chips, broken pieces and other waste material may be collected and distributed among the woodcutters and in certain localities, the twigs and branchwood may be spread over the area, either as in the Alps to protect the young growth against cattle, or as in *jhumes*, to facilitate the burning of the surface before sowing an agricultural crop.

SECTION IX.—ESTIMATING THE YIELD.

1. *Numbering the Lots.*

As soon as the felling operations are over, the amount of material produced must be calculated and its value estimated.

If the clearance of the area and the transport are carried on simultaneously, and the wood is removed to a considerable distance from the felling-area to valleys or rafting-stations and collected there, the estimation is effected at these places, and in the case of summer fellings often not till the following spring.

Each log or butt, and each pile of 100, 50 or 25 poles, &c., each stack of firewood, and each 25 faggots, form the several lots. Current numbers are, therefore, affixed to each separate lot, to distinguish them from one another.

In order to render the control of timber-export effective, it is better that one series of numbers should serve for a whole forest range, or for a group of fellings the produce of which passes in a certain direction. In order, however, to obviate the inconvenience of using very high numbers, each class and sub-class of produce is numbered separately, so that there are several series of numbers each beginning with No. 1 for the logs, butts, hundreds of poles, stacked wood or faggots. In Prussia and some other countries, each species of wood, such as beech-logs, oak-logs, &c., receive different series of numbers.

The numbering may be done by hand, by means of a piece of softwood charcoal, a red pencil or by Faber's numbering chalk, the marks of which last for two years. A paint brush and black oil-paint may also be used with or without stencil-plates. Certain steel dies have also been invented, of which Göhler's revolving die-hammer (fig. 157) is most effective and at present extensively used. According to R. Hess, it is less laborious to number the lots by hand, but the figures impressed by the apparatus are more durable and legible, and with Göhler's revolving hammer 2,000 to 3,000 logs may be numbered in a day.

FIG. 157.

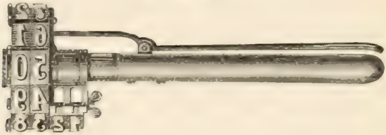
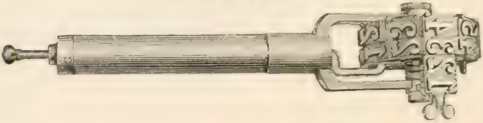


FIG. 158.



Another revolving hammer by Sedelmayr, somewhat heavier than that by Göhler, is shown in fig. 158. Logs and blocks are usually numbered at their ends; in the case of split wood, one large billet is pulled forward from the stack to receive the number; stacks of poles and smaller produce and faggots are numbered on a stake driven into the ground in front of the stack. The numbers should be always plainly visible from a road, and so arranged consecutively that any numbered lot may be readily found. The numbering must be done as soon as work on the felling-area is over.

After completing the numbering, the estimation of material is made, the forest manager entering each numbered lot with notes as to its quality in his Range timber receipt-book.

It is usual to have separate books for timber and firewood. The Range timber receipt-book should contain the following columns :—

No. of lot.	Species.	Description.	Length.	Diameter.	Cubic Contents.	Remarks.

In the remark column, entries may be made as to where the lot is situated, for instance, on the upper, middle or lower road, through the depot, or felling-area.

The numbering book for firewood should run as follows :—

No. of lot.	Species.	Class.	Quantity.	Remarks.

2. *Estimating the Quantity of Produce.*

The quantity of produce from a felling-area may be estimated in different ways, according to the cubic contents, or dimensions of the lots.

(a) **Each Lot a Separate Piece.**—When each lot is formed by a separate piece, the volume of the pieces must be estimated separately, either by calculating their cubic contents, or their dimensions.

i. *Cubic Contents.*

In Germany, France, and some other countries, the cubic contents of timber are always measured by the cubic meter, but in

England, India and N. America by the cubic foot. Without complicating the procedure by considering logs as truncated paraboloids, the simple method is always adopted of multiplying the sectional area at the middle of the log by its length. The cubic contents alone, however, are no exact indication of its value, its length and thickness and the diameter of its smaller end must be also given.

It is customary on the continent of Europe to measure the length of logs in meters, and even decimeters (m. 0·2, 0·4, 0·6, &c.); the diameter in centimeters, and the cubic contents in cubic meters to two decimal places.

[In English measure, the length of logs is given in feet; the diameter, or quarter girth, in inches and the volume in cubic feet without fractions. Logs of valuable wood like mahogany are however sold by the superficial feet.—Tr.]

Whether timber should be measured with or without bark depends on local custom. In the case of winter-fellings, the bark is included, and wherever summer-felled or other peeled wood is measured, 12 to 15 per cent. is added to the cubic contents to allow for the absent bark. This is done because the yield of the forests in the working-plan is estimated with the bark on the trees, but the German timber-trade is most anxious that bark should not be included, and this method Gayer strongly recommends for adoption everywhere in the interests of uniformity.

A universal system of measuring timber without bark presupposes that the bark of logs is removed at the measuring point, and that no addition is made for peeled wood. In the case of coniferous logs, the difference in diameter between barked and unbarked trees is ¾ inch on the average, somewhat more in the case of pines, and for logs under 10 inches in diameter, less than ¼ inch.

In the case of rough, barked broad-leaved trees, such as oak and ash, the bark is 12-15 per cent. of the total volume; in the elm, up to 18 per cent. and more; the birch 11 per cent., the Scotch pine, 11 to 15 per cent., spruce logs and blocks 12 to 13 per cent.; silver-fir ditto 17 per cent. and more. It should be noted that on good soil with a dense growth, the bark is least, whilst in unfavourable localities and open woods it is at a maximum.

Whenever stems are sold at their full length, the measurement for timber naturally stops where the small end becomes less than the minimum in timber-classes, and the rest of the log can be measured only as firewood.

ii. *Measurements according to Dimensions.*

In some localities, where there is an extensive trade in logs, it has been for a long time customary to arrange them in classes which do not depend on their cubic contents. Thus, for each class (*Holländerholz*, &c. of the Black Forest), a log of average dimensions is assumed as a standard, and by its value that of all other logs in the class is regulated, according to variations in length and thickness at the butt-end.

Thus in the Kinzigthal of the Black Forest, which has been renowned for centuries for its fine logs, a silver-fir log 20 meters (65 feet) long and 46 centimeters (18 inches) at the butt-end, is considered the standard.

In many regions of the Southern Alps, in the same way, butts 12—15 inches in largest diameter are considered standards. Thus traders speak of 2 pieces of 10—12 inches, 4 of 8—10 inches, 8 of 6—8 inches as equivalent to a standard, whilst butts of 15—18 inches are considered equivalent to 1½, and larger butts to 2 standards. A similar custom prevails in Norway.

It is clear that such a method greatly facilitates trading, for the price of each class is a multiple or part of that of the standard log and rises and falls with it.

At the same time it is much simpler to calculate prices by the cubic contents, than where a few millimeters in the diameter of the butt give rise to a considerable difference in prices. Besides it is evident that traders must have experience in the method before they can thoroughly understand all its refinements, and this gives local traders a considerable advantage over would-be competitors from a distance. This naturally reduces competition and prices.

Hence the method is falling into disrepute, and will probably be gradually replaced by that which employs the cubic contents.

(b) **Piled Lots.**—With the understanding that poles and other small classes have been duly placed in lots, all that has to be done here is to count the numbers of lots of each class and enter them in the book. They are also reckoned in cubic meters.

When for instance the forest manager enters half a hundred second class hop-poles in his book, their volume is known, for from the class-tariff the dimensions of a second class hop-pole are known and therefore how many such hop-poles go to a cubic meter.

The cubic contents of poles is measured in the same way, as for logs, but evidently this need be done only in a few cases to determine the average, or experimental tables may be referred to for the purpose. It is to be regretted that there is little general agreement as to the class dimensions of poles, and the volumes of different lots are in a state of chaos.

(c) **Stacked Wood.**—In estimating the quantity of stacked wood and faggots, all that has to be done is to count the number of units of recognized dimensions and enter them in the book, and as the stacks are usually 1, 2, 3 or rarely 4 stacked cubic meters, this is a very simple affair. At the same time, the dimensions of the stacks as to height and breadth should be checked, here and there, by actual measurement. The depth is the actual length of the billets, the correctness of which should be carefully seen to during the conversion. The stacks must also be piled as densely as possible; badly piled stacks should be upset and piled again. The length and girth of the faggots should at the same time be checked, and the number of faggots entered in the book.

3. *Estimating the Quality of the Produce.*

This includes all the points already referred to, such as species, grain, and customs of the market. The species should always be entered in the Range receipt-book, but to enter the other points would lead the manager too far into detail. Taken altogether, however, they enable the forest manager to decide on the quality of the produce and he will pay the more attention to these points, the more valuable each lot is likely to be.

As already stated, the greatest attention should be paid to the quality of the oak-timber and to logs of spruce and silver-fir, which have far to go to reach their ultimate destination. In the interests of trade, it is desirable that such wood should at least be perfectly sound when handed over by the forester to the timber-merchant.

4. *Valuation.*

As soon as the quantity of the produce of the felling has all been entered, and the manager has become acquainted with the quality of each lot, he should proceed to put an estimated price on the lots, in accordance with the latest information he has acquired regarding local demands. The sale-price which the produce will realise often depends greatly on the fact that a proper valuation of it has been made before the sale by the forest manager.

In order to arrive at such a result, he must be thoroughly acquainted with the actual state of the market, and with the technical qualities and defects of his wood, and the purposes for which it is likely to be employed.

The manager should bestow the greater care on the classification of his produce, the more valuable it is, and when full-sized logs of good timber are included, a rough estimate of their value will not suffice. In such cases, the entire log should be valued in length sections in accordance with the uses to which it may be put. As each piece or lot is valued, it should be stamped with the Range-hammer, generally close to the number it already bears. This denotes that the wood has been entered in the range receipt-book and is useful in the control of the transport or in possible cases of peculation.

SECTION X.—CONCLUDING THE BUSINESS OF FELLING AND CONVERSION.

As soon as the Range receipt-book has been written-up, the produce of the felling must be tabulated to show its value, the depot should then be inspected, the workmen paid, and thus the whole business concluded.

1. *Registry of the Amount and Value of the Yield from the Felling.*

The results of the felling, as shown in serial numbers in the Range receipt-books, must now be entered in the Felling-register, which shows the total amount of produce of each class of material and its value. The prices of the units of each class of produce should be average local prices, and are generally kept up to date separately for each range and sometimes termed **timber-royalties** (*Holztaxen*).

At the same time, the produce may be marked for sale in lots which as already stated should be larger or smaller, according to the circumstances of the market (*Vide* p. 293).

As these prices, or royalties, are fixed by units—at so much a cubic meter or cubic foot, per log, per hundred poles, &c. per stacked cubic meter, 100 stacked cubic feet, cord or 100 faggots —all that has to be done is to multiply the number of units in each class by the price of a unit.

The Felling-register usually contains a summary of the whole produce of the felling, and for this the cubic meter is generally used throughout Germany, France, Austria-Hungary and Switzerland.

There is no difficulty in calculating the cubic contents of all the timber and poles, and certain **reducing factors** established by experiment are used to transform all the stacked volume of the firewood, faggots, &c., from stacked to solid measure.

The following average reducing-factors were determined by measurements made in Austria, for pieces one meter long:—

	Hardwood.	Softwood.
Stacked timber	·73	·77
Split firewood 1st class . . .	·67	·68
,, 2nd class . .	·63	·65
,, 3rd class (knotty wood)	·58	—
Round billets	·57	·64
Ditto small	·44	·50
Root and stump-wood . .	·40	·47
100 Faggots	1·61	1·65

Beech, [ash, sycamore.—Tr.], hornbeam and oak are classed as hardwoods; alder, birch, aspen, spruce, silver-fir, larch, Scotch and Austrian pines as softwoods.

2. *Revision of the Record.*

On completion of the Felling-register, or before it is written up from the Range timber receipt-book, the record of the produce of a felling may be revised by a superior forest official. This should be carefully done in the case of valuable timber, but is hardly necessary for firewood.

3. *Payment of the Woodcutters.*

As soon as the full statement of the produce from the felling-area has been prepared, there can be no difficulty in settling accounts with the woodcutters; for by multiplying the contracted rates of pay per unit of produce by the quantity of material, the total amount due to them is easily calculated. Owing, however, to the generally impecunious condition of the men, it is usual from time to time to pay them advances in respect of work done; these are generally made every fortnight, or weekly. The sums paid should be proportional to the work done by the men, which can always be roughly calculated. In order to prevent the risk of over-payment and keep the men at the work, about one quarter of their earnings is kept back till the whole work is done; the balance is then paid to the men after deducting all their advances from the total amount due for the work.

It is generally the duty of the foreman to draw the payment from the forest cashier, and distribute it among the different parties of woodcutters. Wherever the work has been given to a contractor, he will naturally be paid for it in full.

To attempt to pay ready money for the whole work during its progress, as portions of the wood are felled, converted and placed in the depot, is only to introduce complications and unnecessary trouble into the business.

CHAPTER IV.

WOOD TRANSPORT BY LAND.

SECTION I.—GENERAL ACCOUNT OF THE TRANSPORT OF WOOD.

THE largest forest areas are generally found in thinly-populated remote districts, and the forest-owner must, therefore, in such cases, expect only a limited demand for the produce of his forests unless he can improve the means of communication between them and distant markets. The forest-owner often undertakes the transport of his own wood, sometimes directly to the timber-market, or to a place where existing means of communication are good enough for no further trouble on his part in this respect to be necessary. If, however, the transport of the timber is undertaken by agency independent of the forest-owner, the latter should endeavour to improve the means of communication between his forests and the markets, so that wood may be conveyed as cheaply as possible.

The great improvement during the present century in communications, and especially by means of railroads, tends more and more to reduce the cost of carriage, which is a vital question in forestry. It is therefore necessary to connect the forests with the general lines of land and water communication, in order to get full value for forest produce, and especially for the better classes of timber. Although the forest-owner has to face greater difficulties in this respect than any other large producer, yet nowhere has greater energy been recently shown than in improving forest communications.

Formerly, owing to the very defective roads available, owners of large forests had to depend chiefly on themselves for bringing their timber to remote markets, which was chiefly effected by water-transport. Of recent years, matters have altered in this respect, the forests have come more and more into contact with the network of railways, while large capitalists have invested their money in the timber-trade; the forest-owner may therefore leave most of the timber-transport to be done by traders and contractors, and restrain his own action to that of delivering his goods to the latter at convenient depots.

Wood-transport, therefore, means the conveyance of the wood to the more or less remote markets or depots by means of more or less permanent routes. Transport is thus distinguished, by the greater distance over which it acts and the more permanent nature of the routes employed, from **clearance of the felling-area,** although both these measures frequently coalesce, and cannot be sharply distinguished from one another.

Wood-transport is distinguished as **transport by land** and **transport by water,** a short account of each of which will be given; the values of the different methods described will then be compared, and an account will be given of permanent timber depots.

The present chapter deals in detail with land-transport only, the different means of land-transport for forest produce being **forest-roads, timber-slides, forest-tramways** and **wire-tramways.**

In the present book, full details as regards the construction of the different means of communication will not be given, and they will be described only in a general way.

SECTION II.—FOREST-ROADS.

1. *Construction and Maintenance.*

(a) **General Account.**—Forest-roads are undoubtedly the best means of land-transport for forest material, and good forest management must attend strictly to the necessity for intersecting forests with good roads. The chief reason for the preference of roads to other modes of timber-transport depends on their superior durability.

Forest-roads are now constructed not only in plains, hills and low mountainous districts, but even in high mountain-ranges, and are constantly being extended to the less accessible forests at high altitudes.

(b) **Network of Roads for a Forest.**—In constructing forest-roads it is absolutely necessary to proceed according to a well-considered plan, forming a network of roads throughout a forest range or a separate forest.

The planning of this road-network should contemplate not only present demands but also those of the future, and thus consider parts of the forest which will be worked at some future time.

The road-network should therefore be projected and planned for the whole forest, though it may be necessary at present only to construct certain parts of it. The other parts of the network will be constructed, seriatim, as the working of the forest proceeds, and by the end of a forest rotation, the whole projected network will thus be completed. It is, however, indispensable to take in hand the roads for certain forest compartments several years before the regular course of fellings reaches them, so that they may be ready in time. It is especially necessary in mountain-forests, where road-making is most difficult and expensive, that the plan for the network of roads should be thoroughly well devised. In the case of forests in plains, it may be permissible to construct temporary roads, which are allowed to fall into disrepair when all the material for which they were constructed has been transported. This is not sufficient for mountain-forests, where all roads made should be kept in constant repair.

The **main roads** should run through the heart of the forests, and be so directed that they lead to other public roads in direct communication with timber-markets, or to railroads or streams serving for water-transport. The forest-roads are often themselves public roadways. **Subsidiary roads** branch-off from the main roads into the forest, and serve as means of transport from all parts of it. In tracing subsidiary roads, the forester must always keep in view the fact that each of them should serve several compartments of the forest, and, should therefore cut right through the felling-areas or adjoin them, or be connected with them by smaller bifurcations.

The principal forest-road usually follows a valley leading towards the timber-market; it either reaches this valley within the limits of the forest, or keeping more to the high and less broken ground descends to it outside the forest. The main roads should be so arranged as to connect the market with all parts of the forest, by means of the subsidiary roads, without its being necessary for the latter to make any long ascent to reach them.

In level and slightly undulating ground, every forest boundary-line and every forest-ride may serve as a subsidiary road.

In mountainous forests, however, the roads, descending in long curves from the heights to the chief line of communication below, pass repeatedly through the compartments; or roads at different altitudes are connected by means of slides, which are often necessary where the mountain-slopes are steep. The subsidiary roads may also be traced along the narrow side-valleys of the higher mountain-ridges, into which the wood is brought from both sides. In such cases the roads must wind round every intervening spur or rock in order to communicate with the felling-areas.

In the case of an extensive tract of woodland belonging to one owner there is little difficulty in laying out a network of roads, but where the properties are subdivided among several owners, or where the forest surrounds other property, there are often serious obstacles to be dealt with. Old roads which one is loath to abandon are often sources of difficulty. It may also be the outlets from the forest where difficulties arise, when the fields beyond it which should be traversed by well-constructed forest-roads belong to poor or obstinate village communities.

As regards the kinds of road to be constructed, a distinction may be made between **earth-roads, paved-roads** or **chaussées,** and **roads chiefly made of wood.**

(c) **Earth-roads.**—In earth-roads no material is used but that found in the immediate neighbourhood of the road. In the plains the road is lined-out, roots of trees extracted and removed, ditches dug to serve as road-boundaries and for drainage, and the material from the ditches placed on the surface of the road to give it the requisite curvature.

In mountainous forests a horizontal basis must first be given to the road by excavating the slope above its axis and throwing the material below it. Wherever the slopes are very steep, retaining-walls of either stone or wood must be constructed below the road; in such cases the stones necessary for this purpose are nearly always available alongside the road, and with them dry masonry retaining-walls may be constructed; only exceptionally should wood, which is so perishable, be used for this purpose.

Earth-roads may be considerably improved if they pass over clay or limestone, by strewing the cart-track with small broken stones, sand or gravel, or by putting on a layer of clay if the soil is too loose. Whenever roads are much used this must be done if they are to be at all permanent.

If, instead of merely spreading stones on the surface, the cart-track is covered to a depth of 8 to 12 inches with broken stones which are well rammed down, the road is said to be **macadamised.**

In constructing forest-roads the greatest attention must be paid to drainage, and this is of the highest importance in plains and on peaty soil. In hill-roads, drainage is generally secured by their sloping nature, especially on sunny aspects. In order to drain roads on north and east aspects and on level ground, side-drains must always be kept open, and the surface of the road suitably curved. The road must also be raised above the ordinary ground-level, and well aërated by keeping it free from over-hanging trees [although it is well-known that road-side avenues are highly efficient drainers when the trees are not too near the cart-track and are properly pruned.—Tr.] Where sufficient fall cannot be given to the side-drains, and stone is not available, as in depressions on the plains, in alder-woods, &c., every means should be taken for raising the level of the road, and the ditches kept at some distance from it so that the water in them may not permeate into the road and make it soft.

The draught of air is increased by keeping the road straight, clearing broad road-sidings through the forest and cutting-away all overhanging trees.

Macadamised roads have the great advantage over paved roads, especially when gravel and small stones are at hand, of being not only cheaper but actually easier for traffic than the latter, except when very carefully constructed.

(d) **Paved Roads.**—Paved roads are distinguished from ordinary roads by their greater width, and the greater attention paid to the gradient, but especially by the care with which they are metalled. The cart-track in them is excavated, lined with stones or cement, and coarse broken stones are then spread on the surface and firmly rolled down. Several other layers of stones are then superposed, each layer consisting of finer material than the one below it. It is always better to use broken stones, which pack better than round pebbles. Each separate layer is rolled and firmly pressed down. The more gradual the change of size in the material used for successive layers of metalling, the more durable the roadway will be. If small stones are directly placed on a coarse basis, the road soon becomes worse than the simplest macadamised road ; the coarse stones from below work their way through to the surface, rendering it uneven, and forming holes into which material placed to mend the road soon sinks. As these paved roads must be everywhere strongly constructed, the retaining walls, culverts, bridges, &c., must be much more elaborate than on ordinary roads ; frequently solid masonry-revetments must be applied to the steep slopes above them, to prevent landslips, and in any case, slopes of soft material must be terraced and wattled.

The main roads coming from a forest, where the traffic is continual, should be constructed as paved roads or at least macadamised. Even the most frequented subsidiary roads should be macadamised. False economy is never more out of place than in the construction of indispensable forest-roads.

(e) **Roads made of Wood.**—Such roads are not durable and should be avoided as much as possible. In the case of peaty soil and in swampy depressions, they cannot, however, be dispensed with, nor for summer-sledging. They are of three kinds : roads made of **fascines, of round pieces of wood** and **sledge-roads.**

i. *Roads made with Fascines.*

Fascines are used for short distances in crossing swampy ground, which cannot easily be drained, especially over peat-mosses where macadam would sink in uselessly. After digging the boundary ditches of such roads, a layer about one foot deep of spruce or Scotch-pine branches is placed evenly on the track, the larger ends being turned inwards ; on this a layer of moss, heather, bilberry or turf-sods, &c., whichever the locality affords, is laid, and the surface is completed with gravel, iron-pan or clay. Sand alone should not be used, as it soon finds its way through the substructure of the road, and in any case is a bad binding material; sand, however, when mixed with clay or loam, may be used to cover the roadway.

Where roads cross shifting sands they may be similarly constructed.

ii. *Roads made with Round or Split Billets.*

These are also made under similar circumstances to the fascine roads for crossing short stretches of swampy ground. In this case, the lowest layer should consist of middle-sized logs placed close together longitudinally in the direction of the road, and upon them round or split billets of wood are packed transversely, whilst poles are pegged-down firmly on both sides along the edges of the roadway above the billets to retain them in position.

This kind of road is used to prevent the feet of beasts of draught from sinking into swamps, and is also much used for filling-up hollows in the construction of sledge-roads.

iii. *Sledge-roads.*

Permanent sledge-roads are used in the summer transport of wood over slightly sloping ground. In order to reduce friction in sledging logs or fire-wood, the road is laid transversely with middle-sized round billets which are held in position with pegs driven into the ground. Their distance apart should not exceed two feet, so that the sledges may always rest on at least two of them. To reduce friction further, the billets are often smeared with grease, or water is poured on them. In the case of their being too slippery after rain, sand may be strewn on them to increase the friction.

In the Barr forest-range in Alsace, sledge-roads are extensively used, also in most of the forests of the Vosges mountains.

[A much more elaborate sledge-road than those described here has been made in the forest of Tihri Garhwal, in the north-west Himalayas*. Its gradient varied between 5 and 11 degrees, and experience shows that 8 degrees is best, and the sharpest curve has a radius of 20 feet.

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* For a complete account of this sledge-road, see Indian Forester, Vol. XII., p. 366.

The length of this sledge-road is 5877 feet, and the total fall 835 feet. It is constructed of defective meter-gauge deodar railway-sleepers which measure 8 feet × 8 inches × 4½ inches, two sets running horizontally and 2¾ feet apart, being jointed and pegged together by oak-pegs, whilst the transverse sleepers are pegged into them at distances of 2½ feet. The grooves in which the sledges run vary in breadth from 4–6 inches according to the curves, and are ½ to ¾ inch deep, and 2 feet apart. The central part of the roadway is ballasted up to the level of the transverse sleepers to prevent the roadway from shifting, and to serve as a footpath. Guards consisting of half-sleepers are placed on the outside of all sharp curves to prevent the sledges leaving the road.

The roadway itself has in many places been blasted out of precipitous rock and contains 20 bridges and wooden viaducts, altogether 1068 feet long. This sledge-road has proved very economical in the transport of railway-sleepers.—Tr.]

(f) **Horizontal Plan of Roads.**—As regards the horizontal plan of forest roads, sharp curves with a radius less than 100 feet should be avoided as much as possible, especially in mountain-districts, and the roads should run in long sweeping curves. Wherever the transport is mainly concerned with logs, attention should be paid to the possibility of the road being used for sliding the timber or for a forest tramway.

(g) **Gradient.**—It is most important to decide on the gradient of a forest-road. Roads for general traffic have a maximum gradient of 5 per cent., which is also a desideratum for main forest roads, as in such a case, the road may be conveniently traversed in both directions. Forest-roads, however, are generally used uphill by empty conveyances, and those which are laden generally come downhill, so that gradients in main roads may go up to 7 and 8 per cent., and in subsidiary roads to 10 per cent., and even more, according to the manner in which they are used.

Steep gradients should always be avoided for cart-traffic, not only to facilitate the latter, but also to protect the road, which when steep is liable to much injury from the use of the break and owing to erosion by water. Sledge-roads on the contrary require a steep gradient.

Permanent roads should be constructed only after the levels have been carefully laid down. Sledge-roads have been recently constructed in a most perfect form in high mountain-regions, being made of two kinds for sledges drawn by men or animals; they may be termed feeders and main sledge-roads. The latter are confined to the lower ground, and traverse long valleys and serve for the conveyance of the wood to depots. The feeders descend the mountain-slopes from the highest and most inaccessible parts of the forest, they often wind round all kinds of obstacles, rocks are blasted to make way for them, galleries cut along precipices and tunnels bored. By their means the wood is brought down to the main sledge-roads. Wherever sledge-roads run through cuttings in districts with heavy snow-fall, they must be covered with rafters and spruce branches for protection. The gradient of the feeders should not be less than 6 to 8 per cent., or greater than 18 to 20 per cent., though even the latter is sometimes exceeded, but 12 to 15 per cent. are the usual gradients. The main sledge-roads are less steep, and 8 to 12 per cent. are usual gradients, but even a slight ascent cannot always be avoided in their case where a ridge has to be crossed between two valleys.

Ground timber-slides are extensively used in the eastern Schwarzwald, they may also be used as sledge-roads chiefly for the transport of logs. Their gradient should generally lie between 9 to 12 per cent. and may even go up to 18 per cent.

A steady gradient is more necessary in the case of sledge-roads than on roads for wheeled traffic; in the latter case, it is now-a-days considered better to vary the gradient, as this is less tiring to beasts of draught than a uniform gradient which always calls on the same muscles.

(h) **Breadth of Roads.**—The breadth of forest-roads depends on the mode of conveyance used, and the amount of traffic. Main forest-roads should not be less than 18 to 24 feet broad, if the traffic on them is not to be impeded, 6½ to 8 feet being the width between the wheels of a cart.

The subsidiary roads need not have a greater breadth than 10 to 15 feet. The breadth of sledge-roads is still less, for the main sledge-roads 8 to 10 feet, and for the feeders 3 to 4½ feet. The slides may be 6 to 8 feet wide. All roads, however, which are only wide enough for one cart or sledge, must have sufficiently wide places here and there for the return traffic to pass; wherever logs are transported, the breadth of the road must be increased at all turnings, or where curves run round projecting rocks. Otherwise logs must be fastened along the edge of the road on which the projecting ends of logs dragged on small sledges may slide.

In the case of narrow sledge-roads with steep gradients passing with curves over precipitous ground, accidents are avoided by placing logs along the edge of the road, which touch one another at their ends and are kept in place by piles or props.

(i) **Maintenance of Roads.**—Wherever there is heavy traffic, roads suffer much damage, by the use of breaks, &c.; in mountains the rain-water brings down silt and landslips, and may inundate the roads at certain points, so that their surface is constantly being degraded. Continual prompt maintenance and repairs, improvement of the drainage of the road and filling-up all holes and ruts are therefore necessary. Repairs to roads, therefore, require almost as much attention as their construction. The chief rule is not to allow any damage to get the upper hand, but to commence repairing it as soon as the weather is dry. It is often advantageous to entrust the repairs of the roads to trustworthy woodcutters.

[In France there is a separate class of guards employed in the State forests and termed '*gardes cantonniers*,' each of whom is entrusted with the repairs of so many miles of road, both working himself and supervising the other labourers.—Tr.]

In many forests it is customary to place a bar across roads after the season's transport is over, in order to protect them from extraneous traffic. The possibility of doing this depends on the nature of the forest rights and other local circumstances. As a rule, such a practice does more harm than good to the forest. Roads should be open to traffic, and the more they are used and injured by the traffic, the more useful they are, and the higher the net-revenue of the forest will be.

2. *Mode of Conveyance.*

The conveyance of the converted wood along roads to the collecting or sale depots is effected either by men or beasts.

(a) Conveyance by Men.

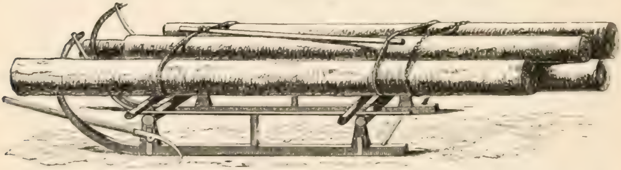
Conveyance by men is almost entirely confined to sledging, which in **transport**, as opposed to **clearance of the felling-area**, takes place on permanent sledge-roads. Only firewood and butts, but not long logs, may be thus transported. In the case of sledges, it is impossible to draw any sharp distinction between transport and clearance, except that in high mountain-regions sledging bears more of the character of transport, and in lower hills, of clearance. From both points of view the methods of sledging have been already described on page 284.

In forests of low hills and plains, no permanent sledge-roads exist, and sledges are only used to convey the wood to the nearest cart-road. In mountainous regions, however, there is no object in merely removing the wood from the felling-area to the nearest road. It is a question of transporting it for miles over permanent sledge-roads down to the valleys to depots, or rafting-stations, at low altitudes; this implies a separate industry not always intimately connected with the felling operations.

i. *Winter Sledging.*

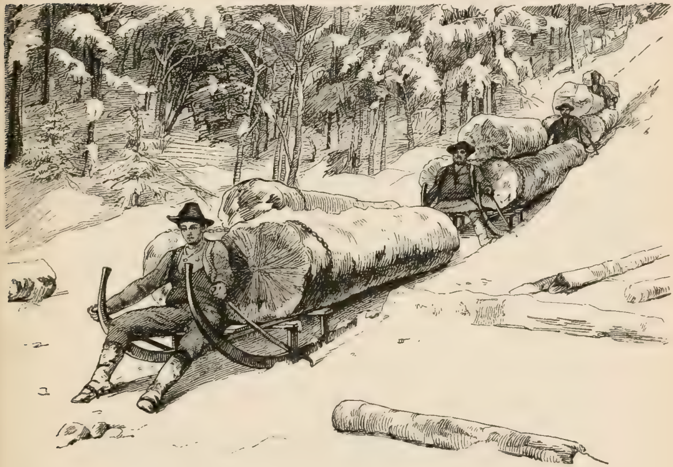
In most cases sledging is done over the snow, and the same kinds of sledges are used as in clearance of the felling-area (*vide* p. 281). Sledges used for firewood have high side-pieces, but for those used for carrying butts, the loads are fastened by means of chains and ropes, and the sledges are longer, as shown in fig. 159, which represents a Bavarian timber-sledge. Before sledging begins, the wood is frequently piled-up in stacks, but usually the sledge is laden on the felling-area and brought thence down to the depot. Wherever sledging is done indepen-

FIG. 159.



dently of the felling operations, and by many workmen acting together, a certain order and uniformity in the operations will be found to be very effective. Therefore, and in order to avoid the constant interruptions which sledges ascending and descending simultaneously would cause in the work, a large number of sledges are laden, and descend and ascend together (fig. 160).

Fig. 160.



The returning empty sledges are sometimes carried back along the sledge-road, but the workmen usually prefer to carry them by the shortest cut, uphill. At the collecting depot the wood must be carefully stacked in order to economise space; or if further transport is down slides or by water, it may be thrown at once down the slide or into the water.

In many mountainous districts as in the Alps, sledging is the usual mode of conveyance of wood; the work is then commenced at the first fall of snow and continued as long as the weather permits. Huts built of wood or stone are provided in suitable places for the workmen, so that they may remain constantly at the work; and these huts also prove useful during felling operations.

The loads which may be transported by a sledge vary with the size of the sledge, the skill and experience of the workmen, the gradient, the nature of the sledge-road, and the distance of the collecting depot from the felling-area.

Much greater loads can be carried down regular sledge-roads than on mere hillside tracks. The load may be 1½ to 2 stacked cubic meters, *i.e.*, 50 to 70 stacked cubic feet. This, however, implies that the sledge-road is in good order, and to secure this the workmen have often to work several hours daily. The amount of wood a man can bring down in a day depends chiefly on the distance traversed, and then on the condition and gradient of the sledge-road. With moderate and uniform slopes and a good road, a man can bring down 3 to 5 stacked cubic meters (100 to 175 stacked cubic feet) of firewood for a distance of about 3 kilometers, say 2 miles; or 10 to 12 stacked cubic meters (350 to 420 stacked cubic feet) to half that distance.

The amount of work done is, however, reduced where the gradient is very slight or excessive, as in the latter case the return of the sledge is difficult; also where the gradients vary, so that breaks have frequently to be used.

ii. *Summer Sledging.*

Sledging during summer takes place on the sledge-road described on page 315, and both firewood and butts are thus transported.

In the forest of Barr, in Alsace, there are 24 kilometers of summer sledge-roads, the longest being 7 kilometers. These roads cost 43 pf. per meter (5*d.* a yard), and the round billets of silver-fir and beech last ten years. The cost of the transport of fuel is 70 pf. per stacked cubic metre (2*s.* per 100 cubic feet); 2 to 5 stacked cubic metres (70 to 175 stacked cubic feet) of firewood form the load, or from 3 to 6 butts, according to the gradient.

[In the Himalayan sledge-road already referred to, two men carry down daily 100–120 meter-gauge sleepers (6¼ ft. × 8¼ × 4¾ inches), whilst they could carry down only 24 on their shoulders, the distance being 1 mile and 1 furlong.—Tr.]

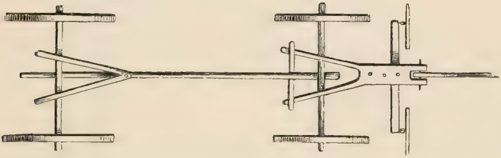
(b) Transport by Beasts.

Transport by the help of beasts is carried on with carts and sledges, and less frequently by dragging or by pack animals.

i. *Ordinary Cart-Traffic.*

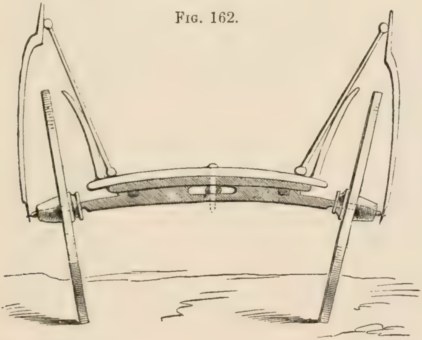
On a dry roadway the ordinary four-wheeled timber-cart is used (figs. 161, 162), and for firewood it must have sides, but for poles and middle-sized logs, these are not required. The wood is secured on to the cart by means of ropes and chains; and specially strong carts are used for large logs and butts.

Fig. 161.



The mode of transport by carts depends chiefly on the quality of the roads, as larger carts may evidently be used on good roads than on bad ones. The largest waggons for firewood are used in the Schwarzwald, and often carry 30 to 36 stacked cubic meters of wood (14 to 17 tons).

Fig. 162.



In carrying long logs, the front and back parts of the timber-cart are separated, and the butt-ends of the logs are placed in front, their smaller ends being suspended under the axle of the hinder pair of wheels, so as to allow for turning at curves in the road. All timber-carts should contain levers, screw-jack, and the necessary chains. If the wheels are high enough, the log is sometimes hung under both axles, which saves the frequently laborious process of lading the timber; and if, in such cases, in descending steep slopes, one end of the logs drags along the ground, it then acts as a break.

ii. *Sledging with Beasts.*

Horses are generally employed in timber transport, although bullocks are very serviceable, and replace them in certain districts on the Continent.

After a fall of snow, the sledge (fig. 164), when laden with firewood, may be conveniently dragged by a horse or bullock; it is larger than the ordinary sledge, and has short horns and two shafts. For the transport of butts, the short sledge (fig. 163) is used, and in this case the butt-ends of the logs are fastened to the sledge by chains and nails, whilst their smaller ends rest on the ground. The break consists either of a bundle of firewood attached to a short chain, or an ordinary break, as shown in fig. 163 or 165, on which the driver stands.

Sledging by the help of horses is extensively followed in the Bavarian Alps.

iii. *Dragging by Beasts.*

Dragging logs by beasts is often impracticable on ordinary roads, on account of the great damage which would ensue.

iv. *Use of Pack-Cattle.*

In Germany the use of pack-cattle, mules, or ponies for the transport of firewood or charcoal-wood, is limited to the Alps, where the wood which has been collected lies scattered over a large area. A horse carries only 4 cwt., while it can drag 14 to 18 cwt. At the same time, pack-animals require only bridle-paths, which can be much more easily and cheaply constructed and kept in repair than cart-roads.

[In the Himalayas the transport of firewood is extensively carried on by means of pack-mules and ponies, in billets 2 feet long, and the cost of conveyance is 1 rupee 6 annas per 100 stacked cubic feet per mile for oakwood, and 1 rupee 2 annas for fir.—Tr.]

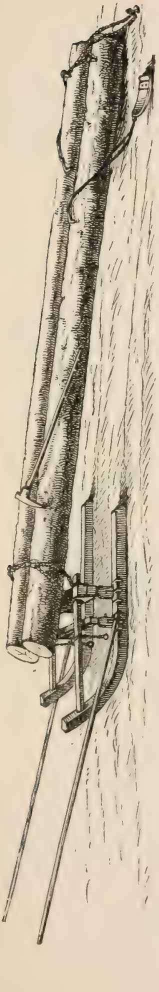


Fig 163.

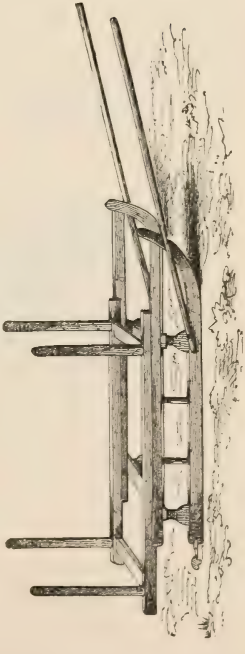


Fig. 164.

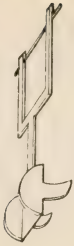


Fig. 165.

SECTION III.—TIMBER-SLIDES.

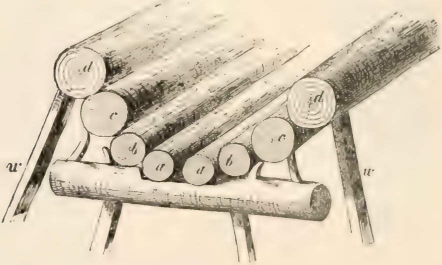
A timber-slide is a more or less permanent channel, either constructed of wood or excavated in the ground, and placed along a mountain slope: the wood descends in it by its own weight. Slides may be distinguished as **wooden slides, ground slides,** or **roads used for sliding timber.**

1. *Wooden Slides.*

Wooden slides may be constructed either of butts or poles, or of planks.

(a) **Log or Pole Slides.**—These are semi-circular channels, made of closely-packed poles, or logs, 4 to 12 inches thick, and are used for timber transport. The pieces of timber used in constructing ordinary slides of this kind should be 16 to 26 feet long, and the separate sections of which the slide is made are the same length as the pieces. The length of a slide is thus frequently described by the number of sections it contains. The channel has a width of 2½ to 5 feet: it rests on strong wooden supports, which may be termed **block-sleepers,** and are made of different shapes. Owing to the great weight of the slide, which naturally tends to drag it down-hill, this tendency being increased by the shaking to which it is subject whilst sliding is in progress, the block-sleepers must be supported by props on both sides to keep them steady. Only when the block-sleepers are sufficiently

FIG. 166.



massive to preserve their own stability can these props be dispensed with. The lowest section of a slide is very strongly made to resist shocks, and is either horizontal or inclined upwards, in order to moderate the fall of the wood as it slides-down. It should rest on strong blocks of wood driven into the ground, and the effect is to shoot the descending piece of wood upwards in a curve, so that it may fall without any great shock (fig. 169).

As a rule (fig. 166), each section consists of six poles, two (*a a*) forming its base, two (*b b*) the sides, and two (*c c*) the edges of the slide. In curves, one of the pieces *c* may be omitted on the inner side. Where the gradients are very steep a second pair of poles (*d d*) may be added. The wood on the inside of the slide is all barked.

The different sections of the slide are joined together as shown in fig. 167. The pieces (*a a*) fit into the groove of the block-sleeper (fig. 168), the pieces (*b b*) rest between the former and pegs driven into the block-sleeper, and (*c c*) on these pegs and two others similarly fixed; they are also kept in place by props (*w*), (*d d*) when used are similarly supported.

FIG. 167.

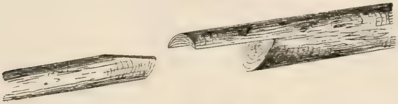
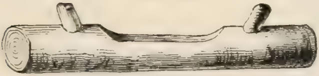


FIG. 168.



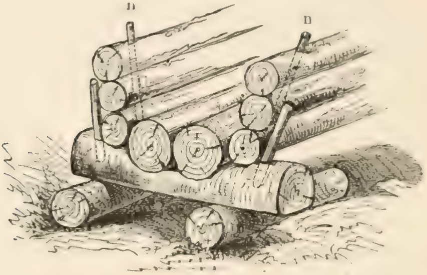
The construction of slides in the Black Forest is somewhat different, as shown in fig. 169, where all the poles, except the two lowest, are bored by augers, and kept in position by strong beech trenails. In some cases a plank is used for the bottom of the slide.

The trestles which support the block-sleepers vary in height, according to the nature of the ground, or the block-sleepers may rest directly on the ground.

In the Black Forest and the Tyrol, the block-sleepers usually rest on round billets.

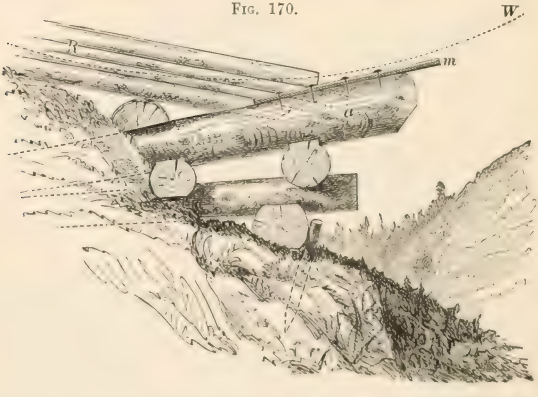
Fig. 170 shows the mode of construction of the end-section of a slide, (*m*) being a plate of wrought iron, over which the descending pieces slide, and which, owing to its elasticity, propels them upwards before they fall.

FIG. 169.



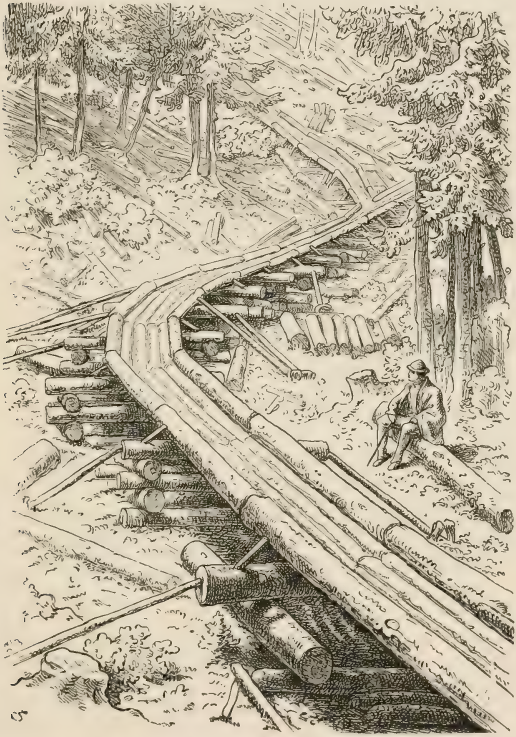
Slides intended for the transport of logs must be constructed in a much stronger manner than those for firewood, and it is then chiefly the side pieces (*b* and *c*) which must be strongly supported, and logs measuring one foot and one foot two inches in diameter and 50 to 60 feet long may be used.

FIG. 170.



The slide shown in fig. 171 is used for logs in the Triftenthal, in N. Tyrol. It is sub-divided above into two branches, and is chiefly used for bringing down butts; its strength of construction may be judged from the plate.

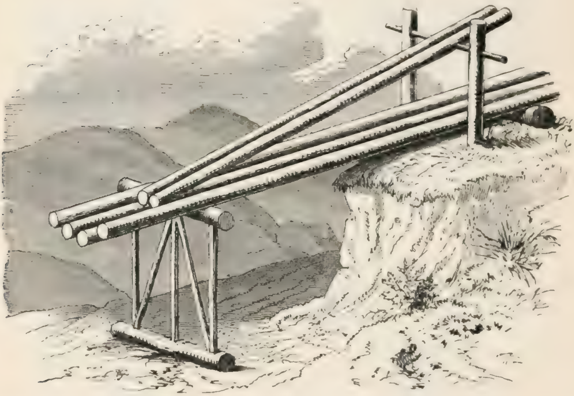
FIG. 171.



When sliding logs 30 to 60 feet long, it must be remembered that where the slide is of any considerable length the logs shoot out from it with great velocity, and to considerable distances, which may extend to 200 or 300 feet in the gently inclined foreground of the slide (in the Salzkammergut and other places).

Arrangements have sometimes to be made to reduce the velocity of logs when sliding, and a mode of break for the purpose is shewn in fig. 172; as the log coming down strikes and lifts the break, its velocity is naturally reduced. Another plan is to lead an intermediate section of the slide upwards, and allow the piece to fall into a side-bifurcation by which the slide is continued. The piece of wood loses all its acquired velocity in this change of direction, and then descends again, until it meets with another break.

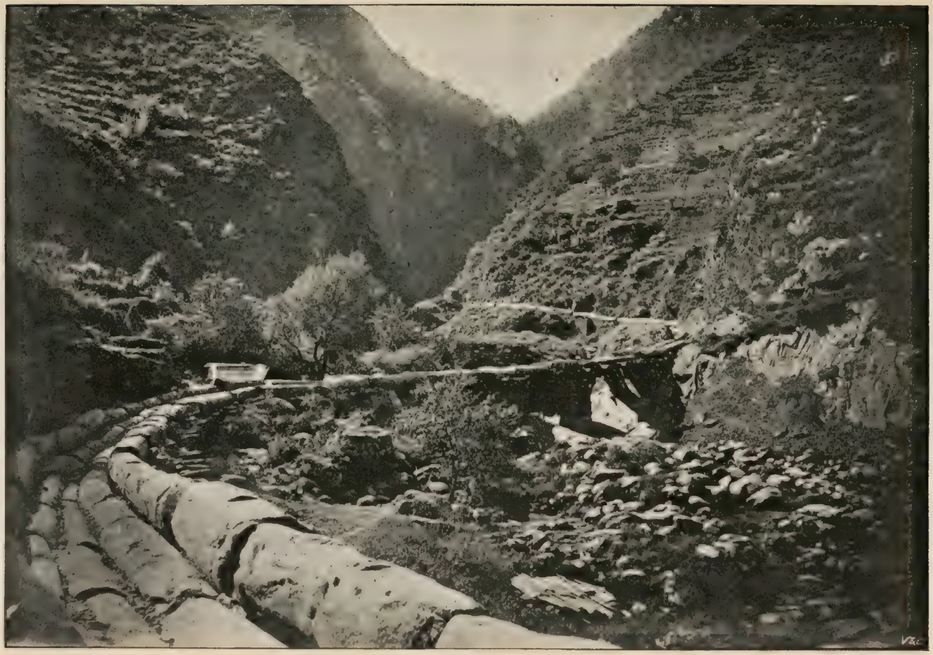
Fig. 172.



[The largest slide of this nature hitherto made in India is the Bakani slide, near Chamba, in the Punjab. It is 12,539 feet long, with a vertical fall of 1,650 feet, or an average gradient of $13\frac{1}{3}$ per cent. It is formed of 4,000 deodar-logs of various sizes, of which there are 4–6 in a cross section, and they are generally embedded in boulder ballast, and when the present working of the forest-block has been completed these logs will be removed and exported as timber. Where the line is above the ground-level, the slide is supported on piles made as follows:—

Two logs, about 8 feet long, are placed 10 feet apart in line with the slide, cross-wise on these are placed 2 others 12 feet long, notches in their ends fitting into corresponding notches in the others, then 2 more longitudinally and so on, till the required height is reached

Pl. III.



TIMBER SLIDE IN THE CHAMBA FORESTS.

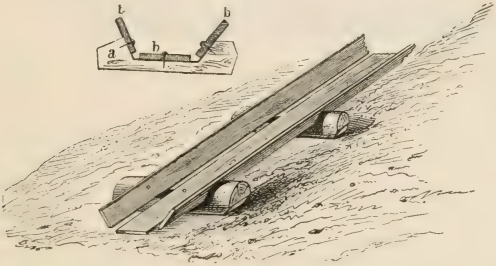
The middle space is filled with boulders, and the outer frame-work is also packed with dry stone-masonry to give solidity to the piles.

The largest log sent down was 48 feet long and it descended for 2,500 feet, at the rate of 20 miles an hour. (*Vide* Plate III.)—Tr.]

(b) **Plank-slides.**—In plank-slides, as shown in fig. 173, the base and walls are made of planks, which are let into the block sleepers, and firmly nailed to them.

[In the Lambatatch Forest in Tihri-Garhwal in the north-west Himalayas, a slide of this kind, $2\frac{1}{2}$ miles long, was made by simply wedging together two vertical and one horizontal planks, each measuring 13 feet × 12 inches × 5 inches, into block-sleepers. It was used for broad-gauge railway-sleepers. This slide was 1 mile 1,052 feet long and the fall 2,687 feet. Breaks formed of 2 and 3 inch planks placed 15 feet apart were used to stop the velocity of the sleepers, but this proved of no avail and the slide was then divided into two sections, the steeper part being covered in with planks. A little water was admitted to prevent the wood from taking fire, which eventually happened to the lower part of the slide, down which the sleepers went at 3 miles a minute.—Tr.]

Fig. 173.

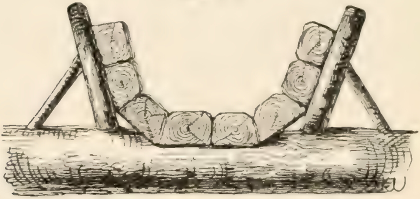


Plank-slides are extensively used in the Black Forest. If plank-slides are to be used for the export of large quantities of timber they must be strongly constructed, but when only for temporary use, the sections are lightly built, and transportable as shown in fig. 173. In this case the ends of the planks are sloped-off and fastened by screws to those of the next section. These portable slides are largely used for firewood in the Sihlwald, near Zurich.

(c) **Wet Slides.**—The description of slides will be completed by an account of wet slides, which must be made as nearly water-tight as possible, so as to hold a moderate stream of water, and must therefore be much more carefully constructed than dry-slides.

As fig. 174 shows, they are generally made with eight hewn poles, the sides of which fit closely, and the interstices are stopped with moss, or with tarred tow, &c.

Fig. 174.



[A wet slide in the Deota Forest in Tihri-Garhwal in the N. W. Himalayas, was constructed in 1876-78 being 12,192 feet long with a fall of 1,300 feet, the gradients 5-22 degrees, and the best gradient 15 degrees. It consists of a trough composed of three planks (12 feet × 13 inches × 5 inches) roughly joined and firmly wedged into block-sleepers. Being made of *Pinus longifolia*, the latter only last 3 or 4 years, but should be made of deodar-wood, which is very durable in the hill-districts of India. The slide is worked by means of a good flow of water which is supplied by troughs at intervals of about a quarter of a mile, a good depth of water being required when the gradient is less than 18 degrees. When there is plenty of water, 1,200 railway-sleepers can be passed down in about 10 hours, each sleeper taking ten minutes on its journey. (*Vide* fig. 176.)

An account of this slide is given in the working-plan* of the Tihri-Garhwal Forests.—Tr.]

For short wet slides, where there is a plentiful supply of water, preference should be given in their construction to merely hewn poles, instead of planks, as repairs are thus facilitated.

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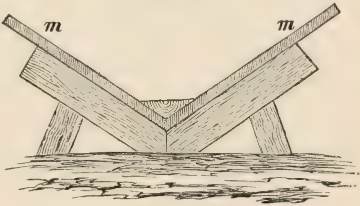
* By N. Hearle, published at Allahabad, for the Government of the N. W. Provinces, 1888.

Water is brought into the slide whenever it passes any stream or spring. In the Salzkammergut, planks are used in a similar way to the Tihri-Garhwal slide. In California, hundreds of miles of wet timber-slides have been constructed as shown in fig. 175.

(d) **Gradient.**—The amount of gradient is a most important consideration in constructing slides. Too small a gradient renders a slide useless, and with too great a gradient the wood will leave the slide, and great danger arises to any person who may be near at hand. The permissible limits are 5 per cent. and 35 to 40 per cent., but the way in which the slide is used, and the size of pieces of wood to be brought down, affect the question.

Fig. 175.



Thus there are **dry slides**, **ice-slides**, and **wet slides**.

In the case of **dry slides**, a steep gradient is necessary, which may go up to 40 per cent. and more.

[If, however, the gradient be very steep, the slide should be fairly straight, as, otherwise, the shocks to which it is subjected by wood coming down causes too much wear and tear. There is also always a danger of fire from friction in dry slides with excessive gradients.—Tr.]

As a rule, however, dry slides become slippery owing to the moist air, or may even contain a certain amount of snow, so that in such cases a lower gradient will suffice than if the slide is used when quite dry, as may be the case in hot countries, with scanty rainfall.

In the case of **ice-slides**, water is introduced into the slide during a frost, so that it becomes internally coated with ice, and a very slight gradient is then required.

In **wet slides**, a thin stream of water is necessary, and should be deeper the steeper the gradient.

Besides depending on the manner in which a slide is used, the gradient will also be affected by the size of the pieces brought down, so that there are slides for firewood, logs, or scantling such as railway-sleepers, and in the Alps, for billets two to three meters long used for charcoal.

Slides intended for bringing down logs and butts must have lower gradients than those used for firewood, as the former pieces attain a much greater velocity than the lighter pieces of firewood.

The following gradients are usual :—

Material transported.	Dry slide.	Ice-slide.	Wet slide.	Remarks.
		Percentage.		
Firewood..............	20—35	6—12	5—8	5 % is 1 in 20.
Logs	15—20	3—6	3—6	—
Charcoal pieces	Midway between above.			
Railway-sleepers ...	26	—	6	(The data for railway sleepers result from Indian experience.—Tr.

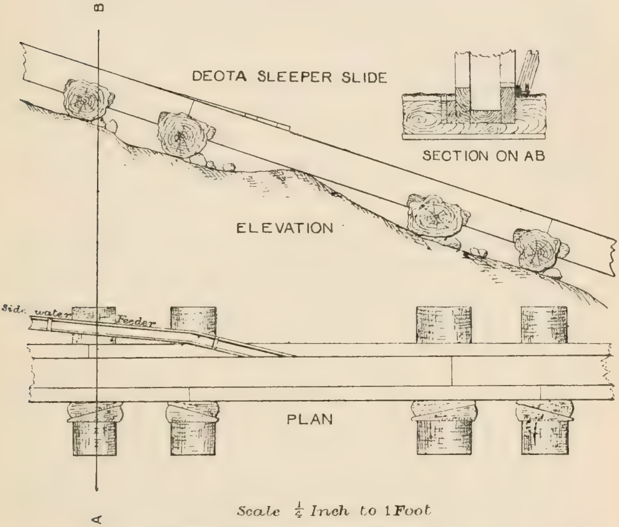
In the case of dry slides, as already stated, the degree of dampness of the air, and the nature of the atmospheric precipitations affect the surface of the slide, and modify the necessary gradient very considerably.

However desirable it may be to give to each slide the most suitable gradient, the nature of the ground frequently renders this impossible, and the gradient is thus consequently greatly modified. As a rule, by using the sides of a mountain torrent, these slides run more or less directly down to the lower valleys, at whatever gradient the bed of the torrent may render practicable. Slight changes of gradient over a few sections of the slide must however be avoided by levelling the base of the slide, either by cuttings, embankments, or constructing viaducts, so that the vertical section of a slide may represent a gradual descent, and there should never be any decided angles between two connected sections.

It is also necessary to secure steeper gradients in the higher portion of the slide than for the lower portion, so that the latter may more and more approach the horizontal direction; the last few sections of it may even ascend, and the longer the slide and the heavier the pieces to be sent down, the more this must be accentuated. As regards the horizontal plan of a slide, it should be straight or form a steady curve without sharp corners, especially for long logs.

(e) **Collecting-places for Wood.**—In high mountainous districts the configuration of the ground will not always allow of the construction of a continuous slide from the lofty ridges down to the valleys, and several transport-works may be made, such as sledge-roads, slides, wire-tramways, &c., according to the nature of the ground in each part. In order to collect the wood coming down from one slide to another lower one a collecting-place may be constructed. It is barred with stout poles with side palisades, and has an aperture below, into which the expanded upper end of the next section is inserted to receive the wood for the next stage of the descent.

Fig. 176.



Scale ¼ Inch to 1 Foot

Drawn by T. Marten, I. Forest Survey.

(1) **Maintenance of Wooden Slides.**—Wooden slides are either **permanent** or **temporary**, the former serving a certain forest tract for a series of years, or connecting a collecting depot high up in the mountains, to which the wood is brought in sledges, with a lower depot in the valley. Such a slide must be most carefully and strongly constructed, and the site for it well chosen, and the gradients very carefully arranged.

Temporary slides are used in bringing-down wood from the upper to the lower part of a felling-area, or to a road, and are constructed in a much lighter and less expensive way than permanent slides.

The construction of slides requires a large quantity of wood, and this is further increased by the slight durability of the latter, for although slides may last longer in damp, shady places, and shorter on sunny aspects, yet they rarely last more than 7 years, and usually repairs are required after 3 or 4 years.

[In the Himalayas, deodar-wood is so saturated with oil, that its heartwood is practically imperishable in mountain districts, and timbers in bridges in Kashmir exposed to alternations of damp and dryness have lasted for hundreds of years, so that very durable timber-slides may be made of deodar.—Tr.]

As progress is made in the construction of roads, slides become less important; at any rate, this applies to slides several miles long, which were formerly so prevalent on the southern declivity of the Alps, where the best constructors of slides are to be found.

Shorter slides, however, intended to complete communications over steep ground, are still extensively used in the Alps and other mountain-ranges, and their use is being extended.

2. *Ground-slides.*

Ground-slides are tracks often found on mountain-sides, and are either made on the bare ground by the repeated sliding of logs, or artificially improved in various ways, so as to be fit for sliding. As a rule, a depression on a steep slope is selected, and a line for sliding dug along it, and pieces of wood placed on it transversely on which the logs may slide, and other pieces placed here and there along the edges of the slide to prevent the logs from leaving it.

In the Black Forest wet sloping meadows are used for this purpose, the line of the slide being bounded by logs. In the Alps the method of sliding along the ground often alternates with timber-chûtes. Ground-slides are used for the transport of logs only.

A ground-slide serves its purpose only when its base and walls are sufficiently firm and smooth; all stones, roots, &c., must therefore be removed, intervening rocks blasted, the way improved here and there by laying down transverse pieces of wood, and in the more difficult places which have to be traversed short wooden slides constructed to complete the work.

It is evident that ground-slides cannot be maintained in workable condition for any prolonged length of time. If they have no rocky subsoil they are soon torn-up by drainage water, and may become buried in silt, gravel, and other debris.

Sometimes a wire rope is fastened to the logs whilst they descend a ground-slide. A rope is coiled round a windlass at the top of the slide so that as a log goes down attached to one end of the rope, the other end being wound round the windlass ready to be fixed to another log as soon as the former has reached its destination: three or more logs are often fastened one behind the other, and go down together. The windlass works with a simple break arrangement. The logs may also be placed in trucks and these let down a tramway by the rope.

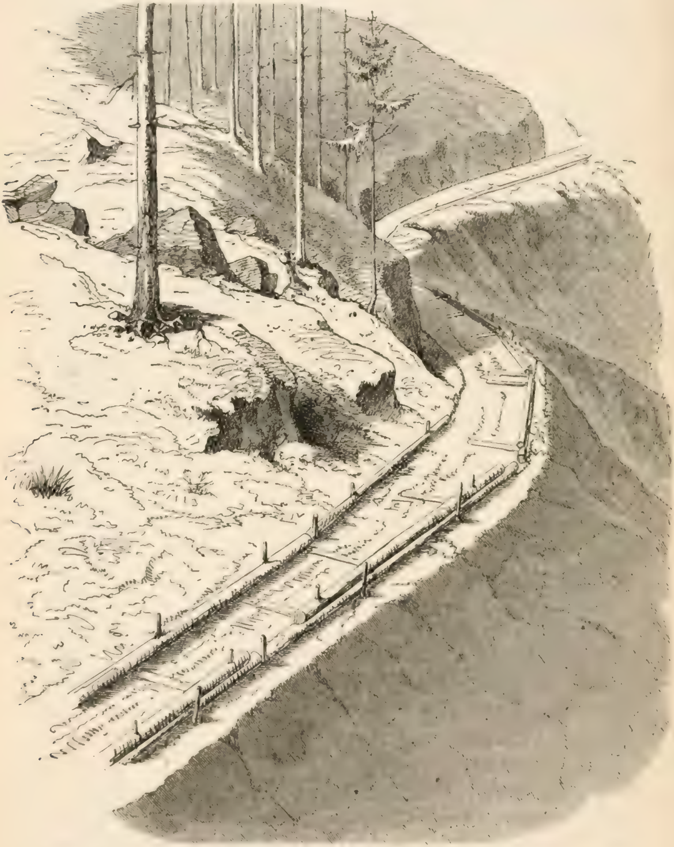
Although ground-slides should possess steep gradients, yet if they are used when covered with snow or frozen, the gradient need not exceed 20 to 25 per cent., especially when they are well constructed, and bounded by logs placed laterally, for in such cases descending logs soon attain a very high velocity.

3. *Road-slides.*

In some valleys leading from the Black Forest, especially those of the Wolf and Kinzig, regularly constructed roadways are used for sliding logs and sledging, as shown in fig. 177.

It has been already laid-down on p. 316 that roads when used as slides should have gradients of 9 to 18 per cent., and more, and should be steepest above and become gradually level below. Although slides should be as straight as possible, and

FIG. 177.

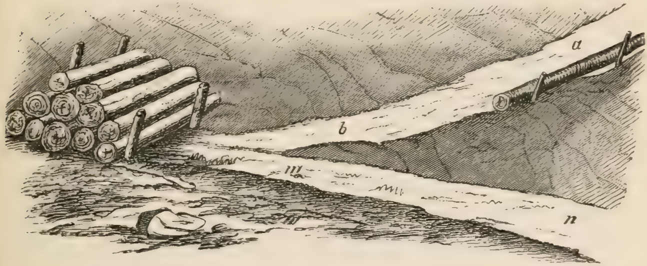


free from sudden curves and angles, this principle may be departed from if the direction of the slide has to change suddenly. A barrier is then erected at the end of a section of the slide at which the downward section begins, and the log, after striking against the barrier, rolls into the lower section (*m*, *n*), and continues its descent as shown in fig. 178.

[A similar turning was effected in a fuel sledge-road near Chakrata, N. W. Himalayas, by using a large cart-wheel set on a pivot as a turn-table, on which the direction of the sledges was changed.—Tr.]

The upper end of a slide is generally somewhere near the felling-area. Its lower end should lead to a plot of land sufficiently spacious for the material brought down to be collected and sorted.

Fig. 178.



In order to manage this better the slide may be divided below into several branches. In any case, it should terminate above a cart-road or a stream used for floating.

Once the logs which are to be transported are brought by any means whatever to the head of the slide, they are used to fix its sides, commencing at the top; being placed along the outer sides, or on both sides, of the roadway, supported by pegs either through the logs or outside them, and at such a distance apart as to allow for the easy passage of a sliding log between them (see fig. 177). In order to prevent descending logs from jamming, the distance apart of the boundary logs should be greater on curves than on straight sections of the slide, or the inner side of the slide may be left free. On the outside of curves it may also be necessary to put two or three boundary logs one above the other, in order to prevent the sliding logs from leaving the slide. In mountain-regions transport on road-slides deserves more attention than has hitherto been bestowed on it; it wastes no wood, is very expeditious, for with a length of 2,000 meters (1⅓ miles), 100 to 300 logs may be brought down in a day, and the roadway may also be used for sledges. Sliding on roads is therefore a highly practical method where cart-traffic is impossible.

Road-slides are now used in Austria, in Galicia, the Carpathian mountains, and the Salzkammergut. In Hohenashau, in the Bavarian Alps, the ordinary sledge-roads are used in winters without much snowfall for sliding 8-meter logs. They are also used in Franconia, but there only on snow or ice, the transport being chiefly confined to butts for saw-mills.

4. *Mode of Transport on Timber-slides.*

The mode of transport of wood on slides is very simple, and depends on the construction and purpose of the slides. Besides launching the logs the requisite labour-force is employed on the maintenance of the slides.

(a) **Wooden Slides.**—The chief object to be secured in the maintenance of wooden slides is to get as smooth a surface as possible. This may be secured by watering the slide during a frost, so as to get a smooth, icy path; by using the snow which lies on the slide, removing most of it and pressing-down the remainder; in wet slides, by using all available water; or generally, by keeping the slide free from dirt, dead leaves, &c., and using it simply as a dry slide.

Slides are chiefly used during winter or early spring, partly on account of the ice and snow, and partly because the wood must be then brought down to be ready for floating when the water rises in the streams in the spring: dry slides, however, may be used throughout the summer.

Whenever, owing to slight gradients of 5 to 6 %, ice-slides must be used, a good deal of labour is involved in watering, one man being required to water and look after every 40 or 50 sections of the slide. Sliding is then often done at night, when the work has been prolonged into spring, and frost only occurs on clear nights. For the most part slides are used either covered with snow, or dry. The work then consists in removing superfluous snow which may have fallen during the night, and in thoroughly freeing dry slides from pieces of bark, wooden splinters, &c.

Owing to the prolonged use of the principal slides, the bottom pieces get worn-away, and pieces to replace them when necessary should always be kept at hand.

During the work of sliding, the logs and other pieces of wood which have been collected at the top of the slide during winter, are thrown in, piece after piece, or they may be launched as they arrive at the top of the slide. The work of sliding is generally done by contract-labour. All the wood should be round, except in slides specially made for railway-sleepers or other scantling, and logs should be barked. In clearing the slide of dirt, &c., the men ascend with climbing-irons on their boots.

In all slides, effective means should be assured of warning men below who may be repairing the slide, before any wood is sent down; also when sliding has been temporarily stopped and the woodcutters have gone to fetch more wood, the men below should be signalled to continue their repairs.

[In the Tihri-Garhwal railway-sleeper slide, a wire for an electric bell at the top of the slide was provided along the line, and men were stationed at intervals, so that if by any chance the sleepers jammed, the men above might be warned to stop sliding any more sleepers till matters had been set right below.—Tr.]

In the case of temporary slides, as soon as all the wood lying at the slide-top has been launched, the pieces which have stopped on the way are sent down, and then the pieces of the slide itself are one by one taken up, and sent down the remainder of the slide. Usually the slide leads down to the stream used for floating, into which the wood falls, but if the logs fall on to the ground at the end of the slide, one or two men must be there to roll them out of the way of the succeeding logs, which might cause breakage if they fell on other logs. All this work is very dangerous to people who may be anywhere near the slide, and the workmen must be exceedingly careful to avoid accidents. Sometimes, for instance, a slide crosses a footpath or cart-road, or there may be interruptions in the slide, or difficult places with insufficient gradient, &c. At all such places men must be posted to warn passers-by of danger, and to expedite the logs, &c., which are descending.

(b) **Road-Slides.**—In the transport of logs by road-slides men must be posted along the slide; they should place fresh transverse pieces under the logs which are sliding-down, or remove some of these pieces, according to the rate at which the logs descend. They should also repair the roadway, where any damage has been done, signal to the men above and below them, and generally expedite the work. On such slides only one log descends at a time, and as soon as it has arrived at the bottom of the slide a signal is given to launch a fresh log, which three or four men effect at the top of the slide with *krempes*.

Road-slides with gradients of 8—12, can be used only in winter. With a gradient of 12—18 they may, however, be used in summer, and the logs always descend butt-end first, the ends of the logs being rounded for the purpose.

SECTION IV.—FOREST-TRAMWAYS.*

It is only during the last twenty years that iron tramways have been used in forests. At first, forest tramways were chiefly constructed of wood, of which those by Leo Presti, von Lippert and improved kinds in Austria-Hungary by Egetz, are the best-known.

Decauville's portable railways, which were used in France for agricultural purposes, have proved thoroughly adapted for timber-transport, and have found many imitators in Germany. Although there may be differences of detail in the various kinds of tramway in actual use, yet the chief points to be secured are **easy transportability** of the plant combined with **strength** and **solidity of construction.**

1. *Kinds of Tramways used.*

If forest-tramways are to be thoroughly useful for timber-transport, they should start from the ordinary country lines of communication, and penetrate along the main and subsidiary forest roads into the interior of the forest as far as the felling-areas, and even up to the individual felled trees.

It follows that some of the lines should be permanently constructed, that a second portion should be more or less portable, and that those sections of the tramways which reach the felling-area should be of light portable nature.

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* Runnebaum. Die Waldeisenbahnen, Berlin. 1886.

Indian Forester, Vol. XII., 1886, p. 244, for an account of a forest-tramway used at Kottenforst, near Bonn, by Sir D. Brandis, K.C.I.E., and Colonel Bailey, R.E.

It is evident that in certain cases the line cannot be continued up to the felling-area, whilst in other cases the portable parts of the tramway communicate directly with the permanent way, and the half-portable portion is not required. In fact, all lines do not include the three kinds of tramway already mentioned.

2. *Mode of Construction.*

This includes **laying-out the road,** the **rails and sleepers,** the **rolling-stock and apparatus used for loading the trucks.**

(a) **Laying-out the Road.**—Ordinary forest-roads will suffice for the main tramways and the half-portable way. They should be as straight as possible, and there should not be much range of gradient, which may reach 8 or 10 °/₀, though moderate gradients from 0 to 6 °/₀ are preferable.

For the main and secondary lines, earthworks to improve the gradient cannot be dispensed with, but the portable portions of the railway must run according to the lay of the ground.

FIG. 179.

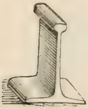
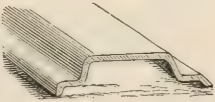
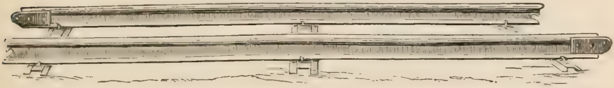


FIG. 180.



(b) **Rails and Sleepers.**—Flange rails (fig. 179) of the best Bessemer rolled steel are used. Transverse sleepers only are used. For the main lines wooden sleepers are used, but for the portable portions of the line steel sleepers (fig. 180) are required, and these sleepers are strongly and permanently united to a pair of rails, constituting a section as in fig. 181. The rails are 4 to 6 meters long in the main lines, but only 2 meters

FIG. 181.



long on the portable lines, and a section must not be heavier than a man can carry (fig. 182), *i. e.*, 35—45 kg. (75—100 lbs.). Whilst on the main lines consecutive rails are fastened together by plates and bolts, in the portable portions they must be attached so as to link and unlink with one another quite easily, as shown in fig. 183.

Fig. 182.

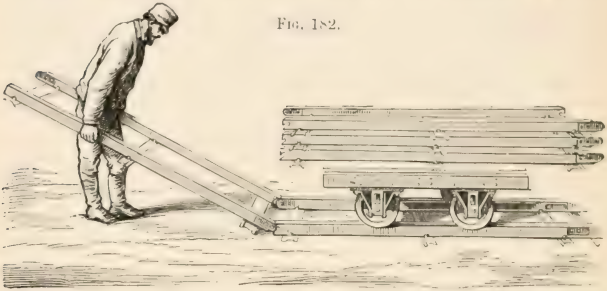
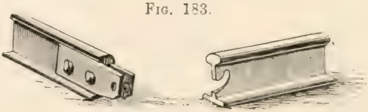
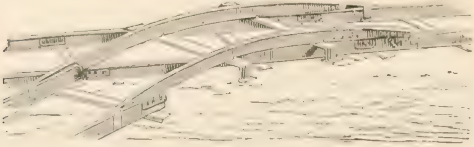


Fig. 183.



As regards the gauge, experience shows that for main lines 70 centimeters (27 inches), and for portable portions 60 centimeters (23 inches), are most suitable.[*] Junctions are effected on the main lines by a combination known as switch and points, a description of which may be seen in Dempsey's Practical Railway Engineer, but on the portable lines a junction is more

Fig. 184.



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[*] So Gayer, but change of gauge is of doubtful efficacy.—Tr.

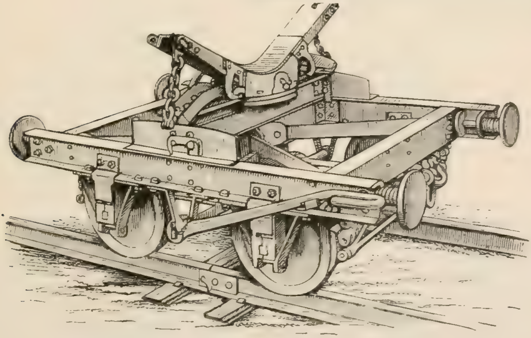
easily effected by means of a curved **section** placed over the rails, as in fig. 184.

[Brandis states that at Kottenforst, wooden sleepers are preferred even for the portable portion of the railway as not liable to bend on uneven ground. Two kilometers ($1\frac{1}{4}$ miles) of branch-railway may be laid by two men in a day. With two wooden sleepers, one at each end, a section weighs 38 kilos = 84 lbs., but the rails must be heavier than when more sleepers are used, 8 kilos per meter.—Tr.]

The main lines might be constructed in similar fashion to the portable lines, but in their case the rails are 5—6 meters long, instead of only 2 meters, and the sleepers 80 centimeters to one meter apart, instead of being only at either end of the portable sections, so that two men are required to lift each section instead of one man. It is also greatly preferable to use wooden sleepers for the main lines.

(c) **The Rolling-stock.**—The rolling-stock, or trucks used for transport, must, though strongly built, be as light as possible It is clear that these trucks must be most carefully constructed, when it is remembered that heavy logs are to be carried, and that the workmen incur considerable danger in moving such heavy pieces of timber. At the same time light trucks are essential, especially on lines with a gradient up to 7 $^{\circ}/_{\circ}$, and without steam-power, as they have to be dragged back to the felling-area by horses, and should as far as possible be made of wood.

Fig. 185.



The trucks are constructed below like ordinary railway-trucks, and support a revolving horizontal plate furnished with an iron crescent-shaped support, or a horizontal bed with inclined arms, on which the logs rest as shown in figs. 185, 188. These revolving plates allow of a log resting on two trucks being taken round curves. Each truck is provided with a break, and different kinds of breaks are used.

Fig. 186.

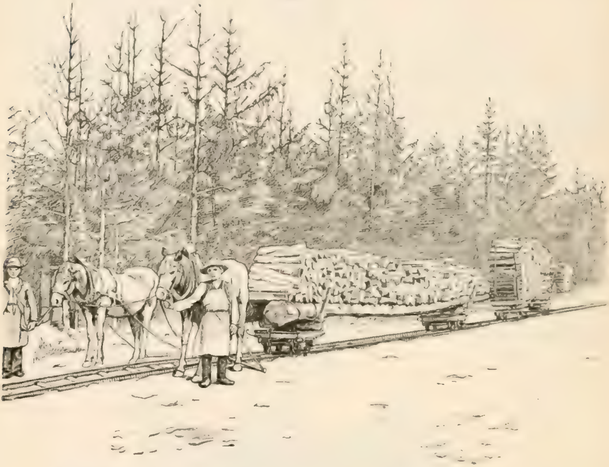
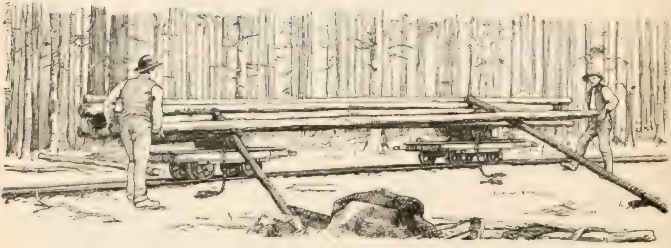


Fig. 187.



For the transport of firewood the revolving plate is not required, but the truck simply forms a platform at its surface, and uprights are supplied on both sides to support the wood.

FIG. 188.

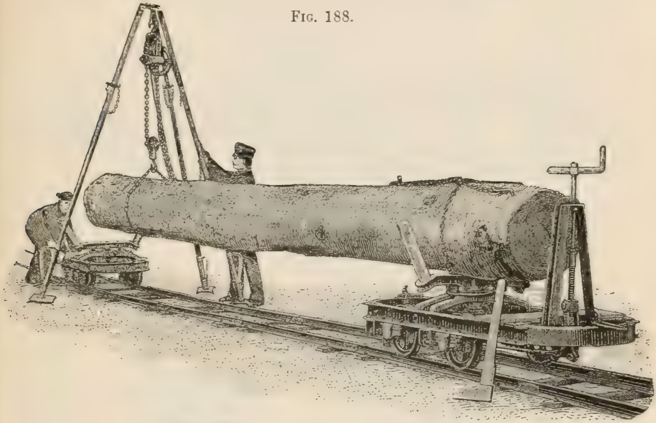


FIG. 189.

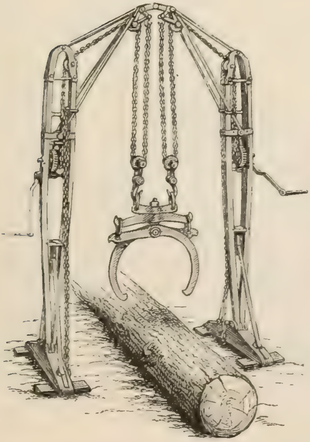
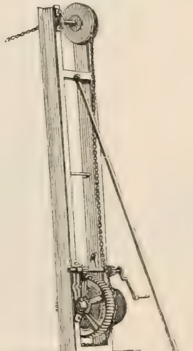


FIG. 190.



The transport of logs can evidently be conducted only by means of two trucks, and firewood may also be piled on two trucks over two scantlings placed longitudinally (fig. 186).

(d) **Apparatus for Lading the Trucks.**—In using forest tramways all suitable mechanical appliances for saving labour should be provided. Although in lading trucks with poles and other light pieces, manual labour alone is required (fig. 187), cranes are supplied for lifting logs on to the trucks. Fig. 188 represents a special tripod crane, and fig. 189 a double crane capable of lifting 4½ tons, which may be

Fig. 191.

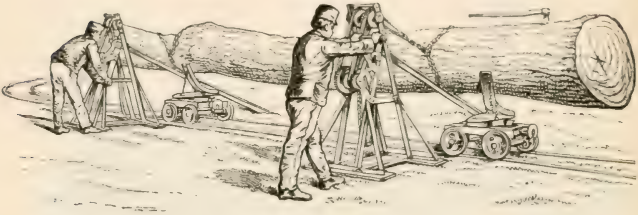


Fig. 192.

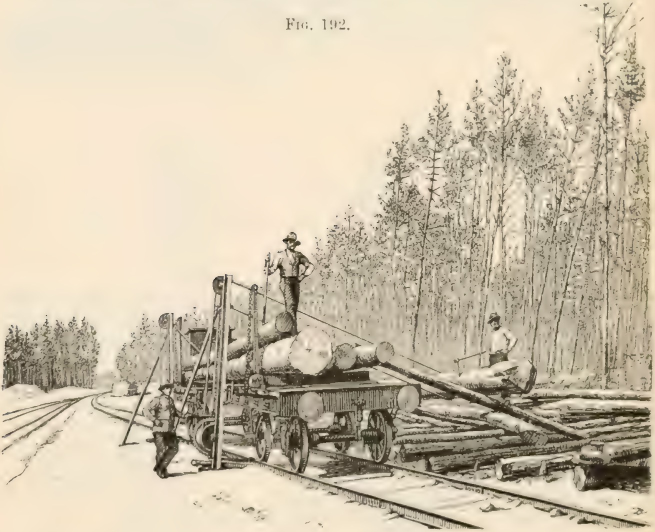
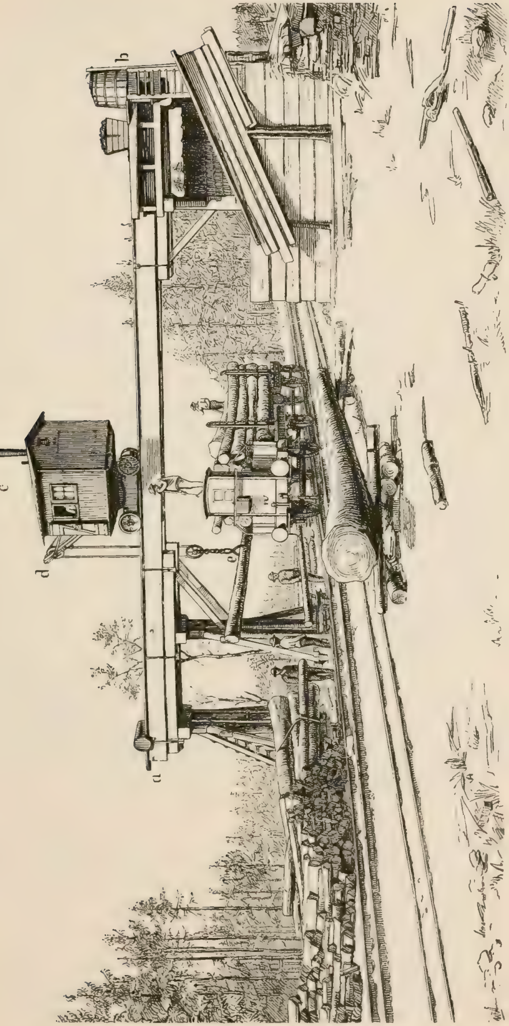


FIG. 193



separated into two parts for convenience of transport, and fig. 191 an improved timber-loader, as constructed by Haarmann at the Osnabrück steel works. [This is said by Brandis to be the safest method for the workmen.—Tr.] Finally, fig. 190 shows an improved windlass, which is very effective, the method of loading by means of it being shown in fig. 192.

By means of these different loading apparatus the log is raised high enough for the rails to be laid under it, and the trucks pushed on to them, when the log is lowered and fastened by chains on to the trucks. Heavy logs must be laden by means of apparatus, and only smaller ones by the use of levers. In the case of firewood there is no difficulty in loading the trucks.

How useful it is to have recourse to machinery, in case of extraordinary demands on labour, was seen in 1891 and 1892, in Brannenburg in Upper Bavaria, when thousands of large logs from trees killed by the "Nun" moth caterpillars in the Ebersberg Forest, were laden on to trucks by a steam-crane as shown in fig. 193.

[The cost of 6 miles of tramway (4 main lines and 1¼ miles branches) at Kottenforst, rolling-stock, loading apparatus, and laying-down 4 miles of main line, in which £40 was spent on earth-work, was £252 per mile and it is estimated to last for 15 years.—Tr.]

3. *Mode of Transport.*

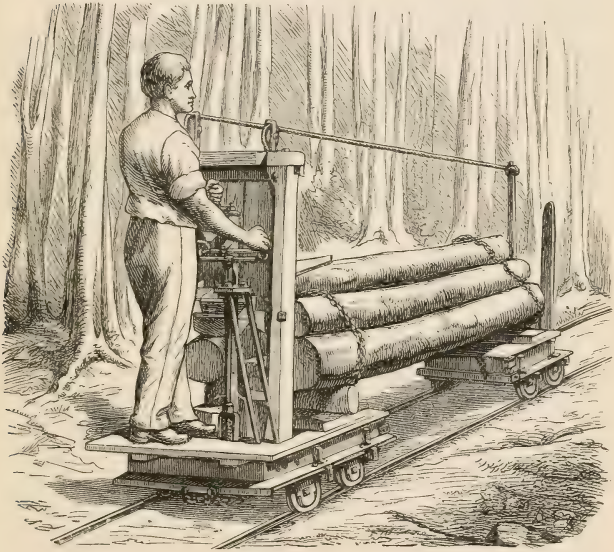
A distinction may be made in forest tramways according to the means used to work them, merely utilizing a **down-incline** of the line of road, dragging the trucks by means of **horses or men**, or finally by **locomotives.**

Where the **incline of the roadway** is used, there must be a fall in it of about 3 to 4 %, and the trucks must be provided with suitable breaks. The empty trucks are dragged back by horses and less frequently by men. This method is employed for short distances wherever the ground is suitable, and is represented in fig. 194.

Horses are used on nearly all branch-lines which are constructed in level land, even when of quite a temporary nature. The horses do not pass between the rails, but alongside of them and are accompanied by drivers and other men, especially when several trucks are united so as to form little trains (fig. 186). Breaks are always required.

At present, on the main lines **locomotives** are used almost everywhere, unless the lines are very short. The locomotives are small, and in mountainous forests specially constructed light, mountain-locomotives with 3 axles are used, which can even travel on curves with a radius of 25 meters (80 feet). In this case the breaks must be very effective. In case the main line is of the ordinary railway-gauge, the ordinary kinds of trucks are used in trains of different lengths, as in the forest of Ebersberg, where 190 truck-loads leave the forest daily, the total annual yield of the forest in timber being 45,500 truck-loads.

FIG. 194.



The loading of the trucks is effected by rolling or sliding over inclined poles as shewn in fig. 187. Special machines for loading are also used, and wherever the timber is transferred from trucks of one gauge to those of another, cranes are indispensable.

Whether the construction and working of a forest tramway is best undertaken by the forest management, or by a contractor, is a question which cannot be answered in a general way; the nature of the locality, volume of wood to be transported, length of the lines, greater or less delay experienced in clearing the felling-areas and several other factors, intervene.

Circumstances differ materially in the case of tramways which are at present being worked. In general, except in the case of railways of the ordinary gauge, experience has shown that it is more economical to construct and work the lines directly, and not by contract, and this quite independently of the advantage to the forest owner in having, in the former case, more freedom in the management of his forest.

Main lines in complete unison with the ordinary railway system of a country should evidently be constructed and managed by railway-engineers. Thus, the 12 kilometers (7½ miles) of railroad in the Ebersberg forest were very rapidly constructed by the 1st Pioneer battalion from the Munich garrison.

4. *Statistics.*

The nineteenth century is chiefly characterised by great improvements in machinery and a consequent complete revolution in the means of transport and communications. Forestry should therefore march with the times, and improve the means of transport in forests which are difficult of access. It is a great mark of progress during the last 20 or 30 years, in such a conservative industry as forestry, that a considerable extension of forest-tramways has taken place.

Dozens of forest-tramways have been constructed in Germany during the last ten years, and there is scarcely a German province in which either a permanent or temporary tramway is not being worked. The first steps in this direction were taken in North Germany, in the different Prussian and Saxon provinces, and South Germany has followed suit, partly owing to the enormous volumes of timber following the great destruction of forests by insects, or storms, in South Bavaria, the Vosges Mountains and Würtemberg.

The oldest permanent forest-tramway is in the Sihlwald near Zurich. The most important forest-tramway hitherto constructed on level land in Germany was designed to remove the enormous volume of timber (4 million cubic meters, or 2¾ million loads) which had been killed by the "Nun" moth caterpillars, in the forests of Ebersberg, Perlach, Sauerlach and Forstenried. This tramway consisted of 12 kilometers (7½ miles) of main line of the ordinary gauge, from the railway-station of Kirchseeon, passing through the middle of the devastated forests, with 40 kilometers (25 miles) of branch-lines, a gauge of 60 centimeters (say 2 feet), and 27 kilometers (17 miles) of portable lines which passed right up to the felling-areas. The construction of this tramway was commenced in August 1890, and it was opened for transport by the beginning of December of the same year, but has now been entirely removed.

The forest-tramways in the German Vosges near Barr, Rothau and St. Quentin are the most important mountain-tramways hitherto constructed. Owing to the nature of the locality, consisting of narrow winding valleys, frequently with steep gradients, many difficulties were encountered during the construction of these tramways, and deep cuttings, viaducts, bridges and double curves are frequent. Thus, the Rothau tramway, 40 kilometers long, with a gauge of 70 centimeters, and worked by locomotive power, ascends 501 meters (1612 feet). The branch-lines of similar construction to that of the main line are 16 kilometers long, with a maximum gradient of 7·14 %.

[In the State forests near Schlettstadt on the river Ill, in Alsace, which are liable to inundations, and where the construction of roads is very costly owing to the spongy nature of the ground, short portable tramways are used to transport the heavy oak and other timber to the banks of the Ill.—Tr.]

[A forest-tramway* has been used since 1884 in the Changamanga plantation near Lahore in the Punjab, for the transport of firewood, and forest-tramways have been used in the Madras Presidency.—Tr.]

For a discussion of the value and suitability of forest-tramways, as compared with other means of transport, the reader is referred to p. 421 of the present book.

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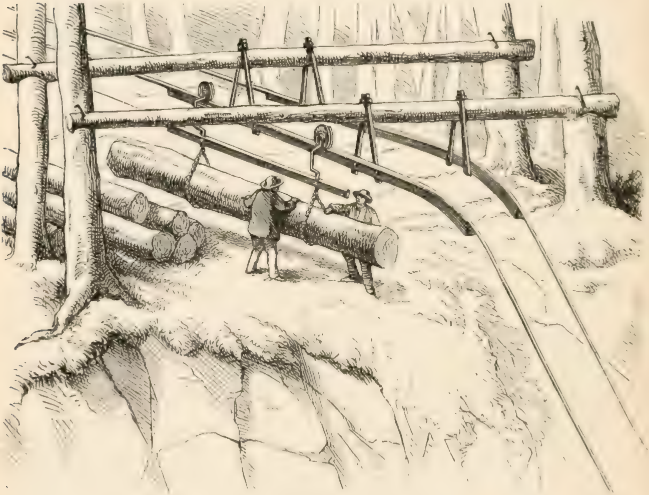
* *Vide* Indian Forester, Vol. XII., p. 349.

SECTION V.—WIRE-TRAMWAYS.

At the end of 1850, the first wire-tramways of the simplest kind were erected in order to convey bundles of firewood and faggots weighing up to half a cwt. down precipitous hillsides. A stout iron wire was used for this purpose, which descended the valley with a gradient of 25–30 % and on which the transported material passed hanging by a hook, or a twisted withe.

FIG. 195.



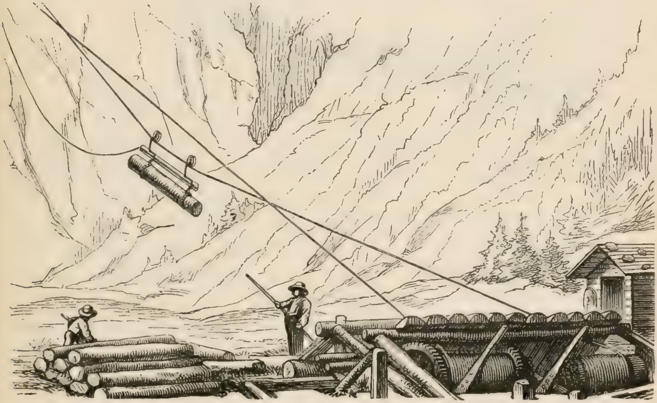
This simple arrangement has more recently led to continual improvements at several places in Switzerland, the Tyrol, and Germany, with the object of transporting larger pieces of wood, and especially logs and butts for sawmills. At present there are two kinds of wire-tramways, those with one or two wires.

1. *Double Wire-Tramways.*

These consist of two wires about 3 centimeters or one inch thick, each of them composed of a wire-rope made of 6 strands of wire closely twisted round a hempen cord and extending without supports from the top to the bottom of a declivity. One serves for the descent of laden cars, and the other for the ascent of the empty ones. The upper ends are fastened to large trees and run over a pair of iron rails, which are curved downwards in front, (fig. 195). The lower ends are wound round horizontal cylinders, which can be turned by means of levers and cog-wheels, so as to stretch the wires (fig. 196).

The log which is to descend the wire, is suspended from it by chains from two wheels (*a a* fig. 197) running on the wire

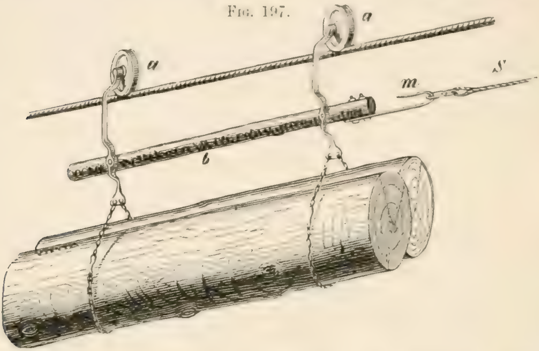
Fig. 196.



and kept at a suitable distance apart by a rod (*b*). This arrangement is termed a truck. Were the laden truck left to itself, it would descend with constantly increasing velocity down the wire, and smash the wood and itself at the end of its course. In order to prevent this and control the course of the truck, a second and more slender wire (*S* fig. 197) is attached to the rod (*b*), and is wound round two rollers at the upper end of the tramway, so that the truck may be let-down and drawn-up again empty. These rollers also serve as a break to regulate the speed of the truck.

The wire-tramway in the Grindelwald, which is shown in figs. 195, and 196, is 4,300 meters (say 14,000 feet) long, and the wires hang quite freely without any support at an angle of about 26 degrees. Another double wire-tramway has been constructed in the forests of the Count of Stolberg-Wernigrode.

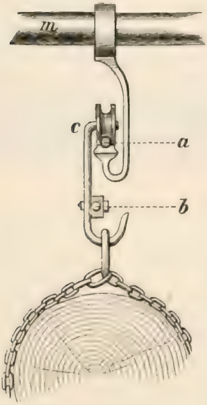
Fig. 197.



It differs from the preceding one owing to its moderate gradient and because the wires are supported at several points by bent iron rods (fig. 198) attached to horizontal poles (*m*) supported by trestles.

In fig. 198, (*a*) is the wire and (*c*) wheel of the truck. This tramway is supplied with a special windlass for dragging logs up to it from distances of 200 meters by means of a wire. The Prince of Schwartzenburg has similar wire-tramways in his forests in Böhmerwald. The largest wire-tramway of this class is at Roveredo, and is 5 miles long.

Fig. 198.



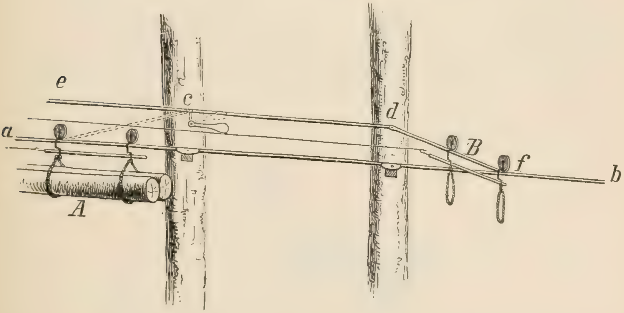
2. *Single Wire-Tramways.*

In single-wire tramways, the laden and empty trucks travel at the same time on a single wire; otherwise their construction is similar to that of the double-wire tramways, the only peculiarity in this case being the arrangement for allowing the empty and laden trucks to pass one another on the wire.

To allow for the possibility of this, at the middle of the wire, where the trucks cross one another, a so-called transfer-station is arranged as follows:—a workman stationed on a scaffolding lifts the empty truck from the wire and replaces it beyond the descending truck so as to allow the latter to pass.

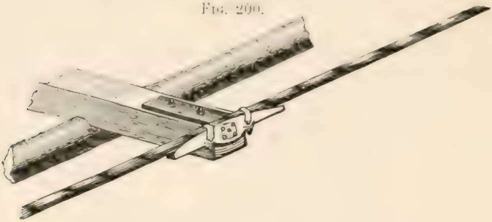
An automatic siding has, however, been invented, as shown in fig. 199: at a short distance above the wire, is fixed, on the poles (*c d*) which serve to support it, a rod (*e c d f*) for the passage of the empty truck. The part of this (*e c*), jointed to the remainder by a hinge at (*c*), has also a counterpoise, so that it remains parallel to the wire unless pressed-down by the weight of the truck, (*c d*) is fixed parallel to the wire, and (*d f*) is also jointed at (*d*) and meets the wire at (*f*). The empty truck *B* on reaching (*f*) ascends (*f d*) and passes from (*d*) to (*c*) whilst the laden truck passes under it, and then rejoins the wire by pressing down (*c e*). The laden truck *A* on reaching (*f*) lifts up (*d f*) and passes on its way.

Fig. 199.



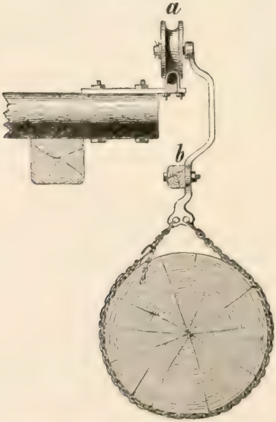
The first single wire-tramway was constructed in Schlierenthal near Alpnach, in Canton Unterwalden, in Switzerland, it has a length of 2,100 meters (1 mile 3 furlongs) and is supported at numerous points, with a gradient of 35°/₀. It differs from the tramway just described by the fact that the wire is supported at the end of horizontal rods to which it is fastened by plates and bolts, so that the wheels of the truck may pass freely over it (fig. 200). The iron rod of the truck supporting the log is also bent outwards (fig. 201).

FIG. 200.



Single wire-tramways have been constructed in the Salzkammergut, in Carinthia, and other places on the southern declivity of the Alps.

FIG. 201.



[In India, wire-tramways have not, hitherto, been successfully introduced for the transport of timber, but are used in hill-stations in the Himalayas and Assam for conveying potatoes or sewage refuse down-hill.—TR.]

CHAPTER V.

WOOD-TRANSPORT BY WATER.

TRANSPORT of wood by water-carriage consists either in **floating** logs, scantling or firewood, piece by piece, down streams, or in **rafting** them, after they have been bound together in rafts.

This is the oldest form of transport known, and is referred to in the Bible in 1 Kings, v., when Solomon rafted large cedar logs from Tyre for the construction of the Temple at Jerusalem. In the Roman provinces (Gau) of Germany, only logs were floated, the floating of firewood being a more recent industry. At present, timber-floating is carried on more or less in many streams, especially in mountain-regions where timber-transport by water is most highly elaborated.

SECTION I.—FLOATING.

Under this section the floating of single pieces of wood to their destination will be discussed.

The section describes :—the **natural suitability** of any stream for floating ; **artificial improvements of streams** ; erection of the **necessary works for the maintenance of a proper supply of water** and **for catching the wood** at its destination, and the **methods employed** in floating wood.

All streams cannot be used for floating wood : they may be too weak or too strong, with too narrow or too wide beds ; they are sometimes too winding ; bad banks, rocks, boulders, &c., may interfere with the floating in an otherwise suitable stream, or floods may effect serious damage. In the most favourable cases similar protection must be afforded to the floating-channel, as to a stream driving water-mills or other hydraulic works, and manual labour is required to conduct the floating. Floating has hence become a highly elaborate undertaking, in the carrying out of which many costly constructions and protective works are needful.

1. *Conditions necessary for Streams to be Utilisable.*

Independently of artificial improvements which may be effected, a watercourse used for floating timber must possess certain natural peculiarities, depending on the **direction, power** and **fall** of the stream. The **direction** must eventually lead to the timber-markets, however much the stream may wind on the way there. Not unfrequently artificial channels are cut in order to shorten the course of the stream.

The **minimum width** admissible is the length of the logs to be floated, as, unless they have room to turn, constant blocks will occur during floating. Only in the case of artificial floating-channels, where the banks are quite smooth, and butts for saw-mills are floated, may the width of the stream be less than the length of the logs.

The **maximum width** of a stream used for floating depends on the possibility of securing and extracting all sunken wood by means of ordinary appliances. Even with the best management some of the heaviest logs will sink, and this sunken wood is either carried along the bottom of the stream, or sticks in holes in its undermined banks. In very broad streams, sunken wood cannot be guided to the shore or otherwise secured. Hence, unless the logs are being rafted, the breadth of streams used should not exceed that of a large brook, or small river.

The **depth** of the water is also an important point; this should be sufficient to float water-logged timber which will not quite sink, without danger of its grounding on the bottom of the stream. Long and slowly running streams should be deeper than rapid streams, which carry the timber better where the distance for floating is short, and there is, therefore, less chance of the wood becoming water-logged. When large, round timber is floated, a greater depth is necessary than for poles and split wood, which is easier to float.

When thoroughly dried, all woods indigenous to Northern Europe will float, but heavy, broad-leaved species lose this faculty much more quickly than coniferous wood; so that while the latter may be floated in the round for great distances, it is not possible to do so with the former. Water-logged wood generally floats vertically. The best depth for floating coniferous logs and split pieces of hardwood is one and a half to three feet, as then the workmen can always wade into the water to secure the sunken wood.

There is no necessity for any uniform **fall** in a stream, and most streams used for floating timber vary greatly in this respect. The best fall is $\frac{1}{200}$ to $\frac{1}{70}$, as then the wood descends rapidly, and is easily guided by the workmen; there is then little wear and tear owing to the pieces dashing together or against rocks, which may also cause continual blocking of the stream and necessitate severe labour to set the logs floating again. Floating has, however, frequently to be undertaken with a fall less, or much greater, than the above. In the latter case, cascades have sometimes to be passed, and much timber is lost.

Rafting can be done with a much less fall, and artificially constructed or improved rafting-streams have falls of only $\frac{1}{500}$ to $\frac{1}{400}$.

The last point to be considered in the practicability of a stream for floating timber consists in the possibility of **artificially damming its tributaries, so as to collect temporarily a much greater head of water than it usually holds.**

There is much periodical variation in the amount of water in a mountain-torrent, and a formidable, destructive torrent may be sometimes seen where a few weeks later there will be merely a little thread of water. In other cases a stream may be always too low for floating, but by collecting the water of its tributaries, enough water may be obtained to float down a sweep of logs.

2. *Improvement and Maintenance of Watercourses for Floating Wood.*

No watercourse is constantly fit for floating without some artificial improvement, but all streams are not susceptible of the same amount of improvement; in many cases the low value of the timber to be floated will not allow of much expenditure at a profit in this direction, and sometimes, the forester has to put up with the mere maintenance of the natural state of a stream. Hence, the works on no two streams used for floating resemble one another. In the following pages the most perfect methods of improving and maintaining a floating-channel are described, so that the forester may select what is practicable in any particular case.

The improvements consist in:—**increasing the head of water** in a stream according to requirements, beyond its average quantity; **regulating the course** of a natural stream; **constructing an artificial channel** to replace it, and **booms** to stop and collect the floated material.

(a) Increasing the Head of Water in a Stream.

Besides rivers such as the Inn, the Isar, the Oder, &c., which are constantly used for timber-floating, nearly all German mountain-streams require arrangements for raising the average height of their water. It is especially the higher parts of streams, near their sources, where this is most necessary, for there they contain the least amount of water, and pass through forest areas where floating is most necessary. The means used for increasing the water are:— **lakes and ponds, feeding-canals, dams and tanks.**

i. *Lakes and Ponds.*

In valleys and mountain-depressions at a high elevation, natural reservoirs such as lakes and ponds are of frequent occurrence, especially in high mountain-ranges with masses of snow and glaciers, where lakes of different sizes are frequently found in the upper stages of the side-valleys. These permanent water reservoirs are very valuable, for they usually lie along the line of floatage, and by means of a simple sluice at the outlet of a watercourse from a lake, the level of the latter may be maintained high enough to furnish a good head of water for floating wood down the stream. Many lakes are thus utilized.

A small lake from which a side-stream passes into the line of floatage, or which may be connected with it by a canal, may also be similarly utilized, and in both these cases the dams to be constructed are similar to those which will be described further on.

ii. *Feeding-Canals.*

Instead of lakes and ponds, watercourses near the floating-channel may be utilized to raise the water-level of the latter by leading their water into it. A mountain-side, through the principal valley of which the floating-channel passes, is often a rich water-collecting basin, its springs and brooks running through the forests ; if here, not only the less important springs, but also the brooks of adjacent valleys are united to the floating stream by canals, and its tributaries provided with sluices, the best possible measures will have been taken to gain a sufficient water-supply.

Lines of levels should be run for these projected feeders, which must often be conducted round spurs and precipices so as to secure, if possible, a uniform fall, which should rarely exceed $\frac{1}{70}$ to $\frac{1}{25}$ or serious damage may ensue. Sluices are required where the feeder leaves the brook, the water of which is to be utilized, and also where it joins the floating-channel, so that swollen torrents may be avoided, and water admitted to the latter only when it is required. It must not be supposed that it is always a difficult matter to lead water from one basin into another, for in the upper parts of a mountain-range several streams may be quite adjacent which diverge widely lower down ; the feeding-canals also are not difficult to construct, being usually mere trenches like those used in irrigating meadows, and it is usual to utilize only tributaries of the same stream which eventually join it lower down.

The direct line of floatage is not often supplied by feeders, but they are frequently used to fill reservoirs.

iii. *Dams and Reservoirs.*

Whenever lakes and ponds are not available, the water of the floating-stream itself may be dammed-up, and thus a stronger head of water obtained. This is secured by means of a **dam** furnished with a **sluice-gate**, which is erected transversely across the valley in which the stream runs so as to maintain the level of the water behind it. A **reservoir** is thus formed, the water in which may be made available for floatage when required, by opening the sluice-gates.

There is much variety in the mode of construction of dams, and according to the material used for them, they are made of earth, wood or masonry.

The chief point is to make the dams and sluices watertight ; cemented masonry-dams are best in this respect, but earth-dams are superior to wooden sluices.

(*a*) **Earth-dams.**—Earth-dams are formed of heaps of earth at the ordinary angle of repose for the material used, as shewn in fig. 202, which gives the section of such a dam. A facing (*a*) of clay or loam is added to the dam on the side near the

FIG. 202.

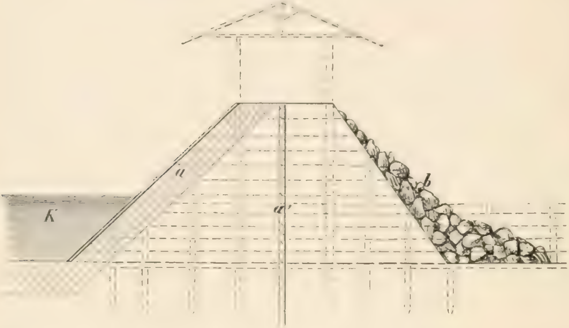
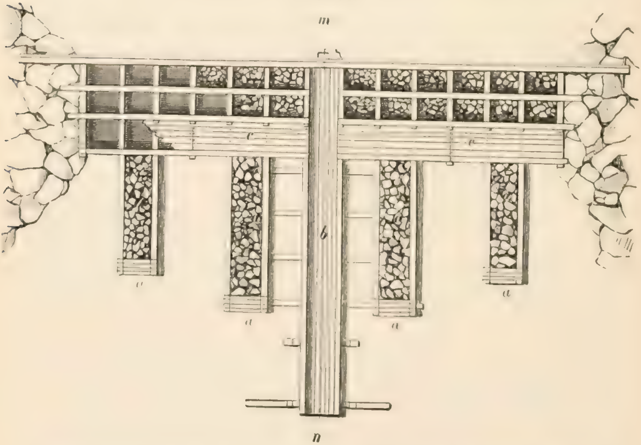


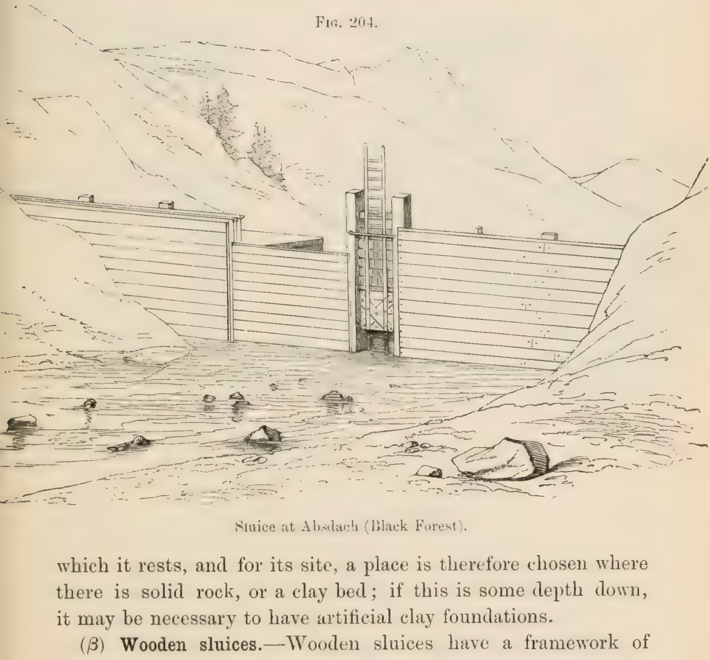
FIG. 203.



The Martin's dam in the Bavarian-Bohemian Forest, which has now been rebuilt in masonry.

reservoir, to make it watertight, and another vertical layer of clay or loam *a′*, in the middle of the dam will prevent rats from perforating it. In order to strengthen the work, a thick facing of rough heavy stones is piled on the side of the dam, away from the reservoir. The impermeability of the dam by water is specially influenced by the nature of the ground on which it rests, and for its site, a place is therefore chosen where there is solid rock, or a clay bed; if this is some depth down, it may be necessary to have artificial clay foundations.

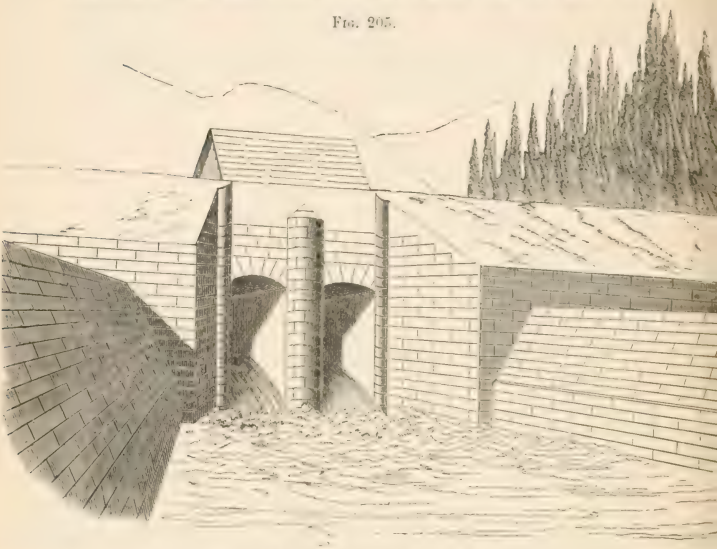
FIG. 204.



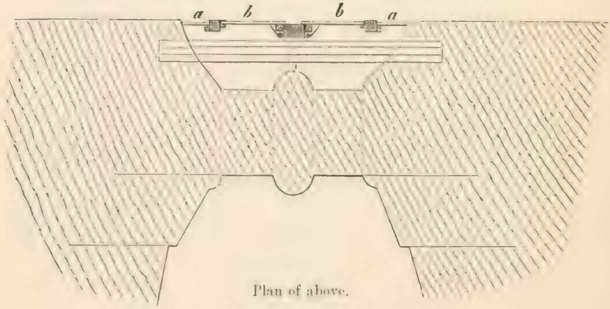
Sluice at Absdach (Black Forest).

(β) **Wooden sluices.**—Wooden sluices have a framework of wood strengthened by means of earth or stones, usually the latter, in which case, the wooden framework is lined with clay and filled with stones. Fig. 203, shows the ground-plan of such a sluice, there being three rows of partitions to be filled with stones. On the side away from the reservoir, these partitions are only half as high as the other two rows, and are planked over (*c*, *c*). A roof is usually placed over the sluice, and it is crowned by a planked bridge. Buttresses (*a a a a*) of somewhat similar construction to the rest of the sluice are added to strengthen the structure. They may however consist only of coarse dry stone masonry; (*b*) is the channel for the passage of the water in the direction (*m n*) and is closed by a sluice-gate.

Fig. 205.



Masonry-dam at Herrenwies (Black Forest).



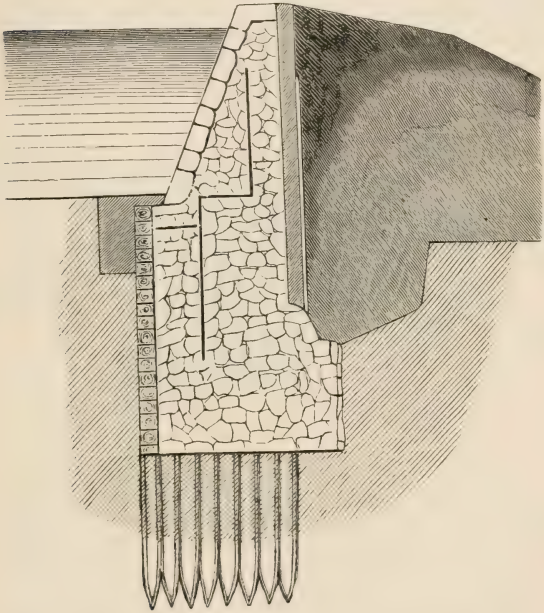
Plan of above.

Fig. 204, shows another weaker kind of wooden sluice in the

Black Forest, at Absdach, on the river Wolf. It consists of piles boarded over, and strengthened, away from the reservoir, by large blocks of stone between which an opening is left for the sluice-gate.

(γ) **Masonry-dams.**—These are very strongly built chiefly or entirely of large hewn stones. As a rule, however, they are only faced with hewn stones, the interior being filled with rammed broken stones, or with gravel or rough stones imbedded in clay; buttresses are then required.

Fig. 206.

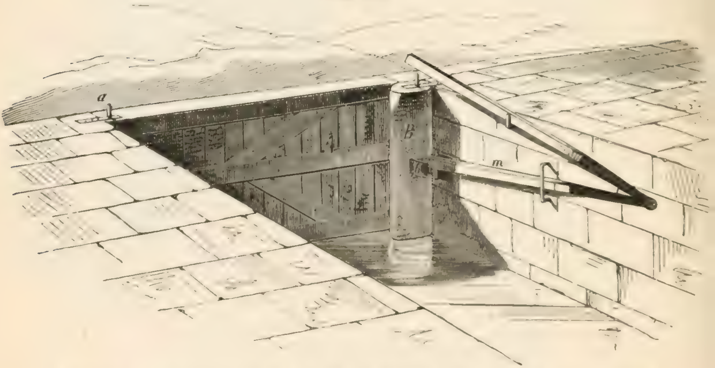


In order to increase their strength, they are frequently made in a regular curved shape, the convex side of which is opposed to the water-pressure, but in that case it must rest on either side on firm rocks, and then resists the pressure of the water like a great vat.

Fig. 205, shows the plan and elevation of a masonry-dam at Herrenwies in the Black Forest, with two sluice-gates (*b b*); (*a a*) are smaller gates which are opened first to relieve the pressure on *b b*.

(δ) **Dams of combined masonry and earth.**—These are the most highly perfectioned of all, and are used in the Bavarian forest, as shown in transverse section in fig. 206. The masonry rests on a foundation of piles, and the reservoir side of the dam is faced with hewn stones resting on cemented rubble-masonry containing a thin layer of concrete. A wall of cement and clay bounds this structure, and a well-stamped earth-dam is continued towards the valley. This mode of construction, and a liberal use of cement and concrete to a considerable depth in the foundations of the dam, make it in the highest possible degree watertight.

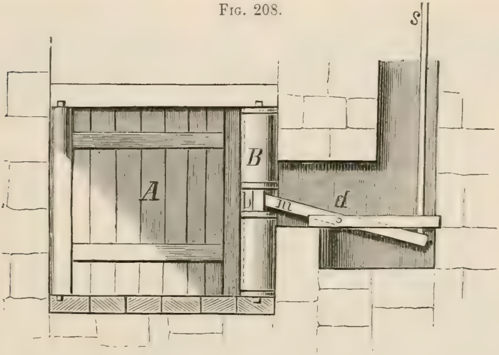
FIG. 207.



(ε) **Sluice-gates.**—The gates for the chief outlet of water from the reservoir are usually in the middle of the dam, but sometimes at its base. The sluice-gates usually open into a channel which conveys the rush of water at some distance from the dam into the natural bed of the stream. This protects the lower side of the dam from being undermined by the water, and is specially important in the case of wooden sluices and earth-dams, as in fig. 203, *m b n*. The sluice-gates are closed by various contrivances, and they may be distinguished, according as they open with a rush, as in ordinary sluice-gates, or are raised gradually, as in the case of vertically opening valves.

(ζ) **Sluice-gates opening in the ordinary way.**—This is effected by means of hinges, but the gates are closed by various contrivances. The usual method of closing them is shewn in fig. 207. *A* is the gate revolving on hinges at (*a*). *B* is a revolving elliptical cylinder of wood, which is kept closed by means of a peg (*b*), a lever placed between (*b*) and the wall of the dam and the pressure of the water in the reservoir, until the lever (*m*) is withdrawn; the pressure on *B* then causes it to revolve on its axis through an angle of 90° and present its smaller diameter to *A*, so that the latter can open, (*b*) entering a recess in the wall made to receive it.

FIG. 208.



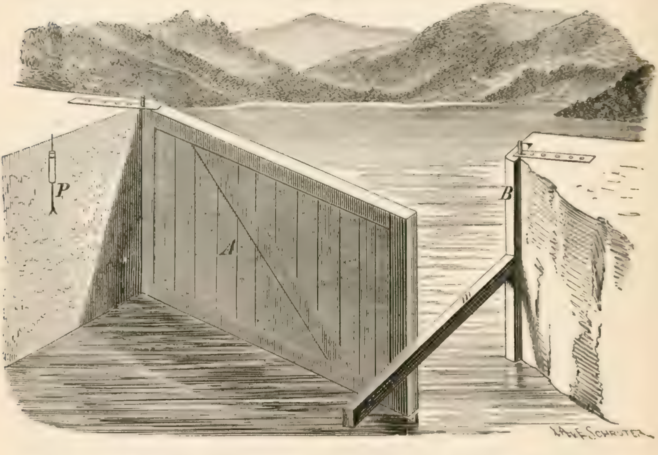
Another mode of opening a sluice-gate is shown in fig. 208: as long as the end (*m*) of the lever (*s d m*) rests against the peg (*b*), the cylinder is kept closed, but when (*s*) is pressed down, (*b*) is released and the gate opens. This mode of opening is chiefly used when the walls of the dam are high.

Fig. 209, represents another mode of opening sluice-gates, where the bar (*m*) is fastened back by an iron pin which fits through a projecting stone at *P*, and can be easily withdrawn.

[In the case of all the above sluice-gates, there is danger of the gate swinging violently against the wall of the dam, and being broken or injured. This is avoided by having the hinge at a short distance from the wall, so that when the gate is opened, there may be a passage for the water between the hinge and the wall of the dam; the intervening water then breaks the force with which the sluice-gate swings, and prevents its striking the wall.—TR.]

It is evident that when the confined water of the reservoir presses with all its weight on the whole sluice-gate, on opening the latter, the violent rush of water would damage the banks below: such gates can therefore be used only where the watercourse below has steep rocky banks. They have also the disadvantage, that the sudden rush of water may not be able to carry downstream all the wood which is lying on the bed of the water-course, so that much of its effect is lost. In the Tyrol, self-opening sluice-gates are used, which open when the reservoir is full.

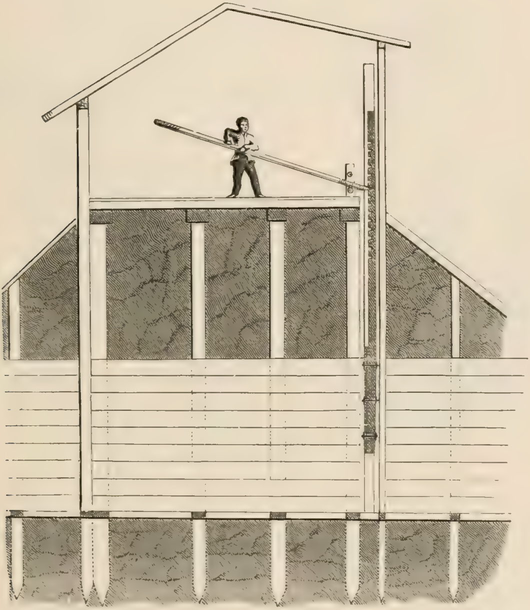
Fig. 209.



(η) **Sluice-valves.**—Sluice-valves are used in well-constructed floating-channels and wherever the banks need protection against the downward rush of water, so that the amount of water passing through the passage in the dam may be regulated at will. These valves are opened by means of a lever fitting into cogs, a ratchet preventing the descent of the valve (fig. 210). In the Absdach sluice, the so-called ladder sluice-gates are adopted, the construction of which may be seen in fig. 204. In order to avoid the use of heavy valves, two smaller ones side-by-side may be used, or several, each of which works in its own groove and may be raised by a revolving axis by means of rollers and chains, or winches.

The mechanism for raising these heavy valves with a small expenditure of strength should be of a very simple nature. Fig. 211 gives a simple combination of cog-wheels and endless screw for the purpose. This mode of raising valves is in general use for the tanks which will be described lower down.

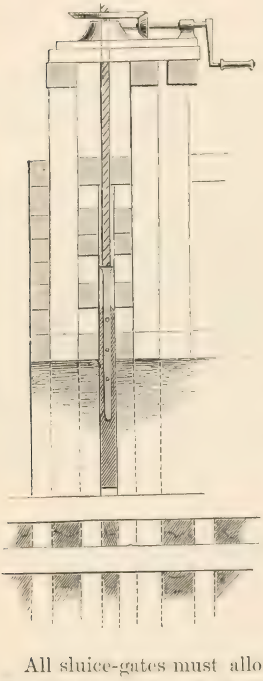
Fig. 210.



(*θ*) **Sluice-gates made of logs.**—The roughest method adopted for closing sluices is to place a number of round logs, split in half, vertically alongside one another, with their ends resting against two strong beams above and below. The crevices between them are then stopped with moss and a pile of earth is often made behind them. When it is desired to release the water, a hook attached to a rope is passed through an iron ring in the central log, which, on being lifted, is carried down by the water; the other logs are similarly lifted out of the way.

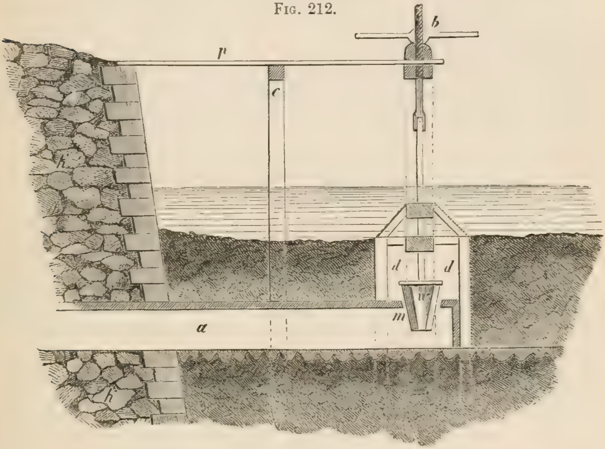
Balks of wood one above the other may also be suspended **horizontally** as is usual in the Black Forest, by chains before the opening, as shown in fig. 205. They are raised one after the other by hooked-poles. Fig. 212, shows the so-called **plug-valve** which is much used, especially in Austrian Silesia. The valve fits vertically into a channel (*a*) excavated under the dam and projecting 4 or 5 yards into the reservoir where it is strongly closed, the open end of the channel leading down-stream. The end under the reservoir is open at (*m*) and can be closed by a conical plug (*n*) which is raised by means of a vertical bar and screw (*b*); (*p*) is a plank bridge for giving access to (*b*). The chamber in which this plug plays is covered with a fine grating to exclude rubbish. This kind of valve weakens the dam much less than any other form of opening for the water, and the water can be allowed to pass through the channel, as gradually as one could wish; it is however very liable to become filled with silt and mud difficult to remove.

Fig. 211.



All sluice-gates must allow for an overflow of excessive water from the reservoir and also for passing a small quantity of water into the floating channel before the principal sluice-gates are opened. The principal rush of water, which is required for floating, passes through the sluice-gates, of which there may be several in the case of large dams, but when once the reservoir is full of water, any more water coming in must be allowed to escape, otherwise the top of the dam would be injured. For this purpose, therefore, a small overflow channel is generally provided at the top of the dam, unless there is a special gate constructed for this purpose. It may also be necessary to completely drain the reservoir of water, in case of repairs, or to free it from sand, gravel, &c.; for this purpose a third opening may be necessary lower down than the principal gates. It is usual to admit a little water into the floating-channel so as to set the logs slowly in motion, before the chief rush of the water comes. This can be done at pleasure by means of sluice-valves, but where there are sluice-gates, a special opening must be made in the large gate for this purpose, unless the floating-channel is provided with a small quantity of water by a side-channel, opening with its own sluice-gate. The size of the principal sluice-gate depends on whether it serves only for the passage of water, or for the wood as well, and in the latter case it must evidently be 4 or 5 meters broad (fig. 204).

Fig. 212.



(ι) **Dimensions of Dams.**—Dams vary much in size; there are some dams which maintain reservoirs capable of submerging a whole valley below them; these are 450 feet long, and over 65 feet in breadth, and in the construction a considerable amount of capital is invested, whilst others can barely raise the level of a stream to its full strength.

The more a water-course is encumbered with boulders and rocks, the lower the dry-season level of its water and the longer its course, the more plentifully should water be supplied.

In such cases, dams are sometimes constructed which allow of a depth of water in the reservoir, at the dam, of 15–30 feet. Well constructed floating-channels with a small and uniform fall require much smaller dams.

Large reservoirs are generally preferable to small ones, even although they take a comparatively long time to fill, as their effects are more proportional to their cost, and the floating is more certain than where several small dams are constructed.

Very large dams have been made in Carinthia and the southern Alps, and in Austria and Hungary.

(κ) **Position of Dams.**—The principal dams are always made in the uppermost parts of a mountain-valley, and their effect reaches for several miles down, so that in many valleys no more dams are required below the principal one. In other cases, however, there are floating-channels with several small dams at distances apart of from 1½ to 2 miles.

Dams are intended, as far as possible, to drive the drainage of a locality into the watercourse which is used for floating. Watercourses, however, contain least water near their sources, but are here most in demand for floating purposes. It is therefore necessary to utilize the first weak run of the water, and wherever it is possible to do so, a strong dam is erected near the very top of a valley, so as to collect as much water above it as possible.

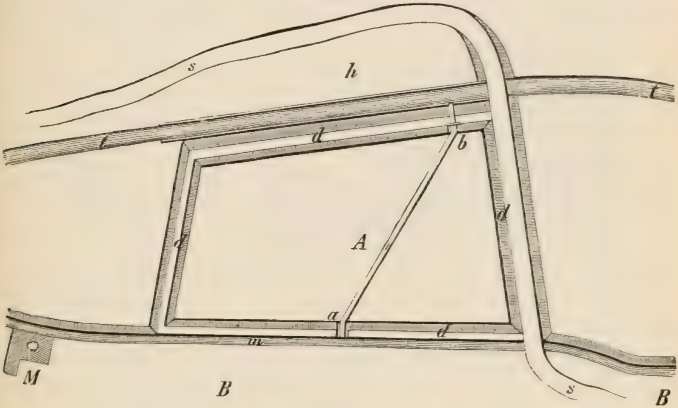
A place is therefore preferable for the principal dam, where the sides of the valley approach one another with rocky walls, whilst above this gorge is a basin-shaped expanse of valley. Such places are often found in mountainous regions.

Care must be taken that the water entering a reservoir is fairly free from silt and gravel, which would soon render it too shallow for use. Wherever this is not the case, special works must be constructed to keep out the sand, &c.; these will be described further on, under the head of weirs.

iv. *Tanks.*

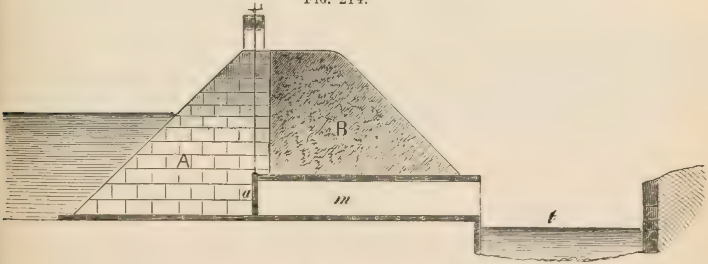
Dams can only be constructed across a stream in narrow mountain-valleys, where they can rest on mountain-spurs on both sides, without being necessarily of any considerable length.

Fig. 213.



In wider and broader valleys with a slight fall, where there are meadows and cultivated lands, and perhaps houses which a dam

Fig. 214.



would obviously inundate, while its cost would be prohibitive, owing to the large amount of compensation involved, it may, nevertheless, be necessary to obtain larger supplies of water for floating timber than the natural course of a stream affords, and this may be secured by constructing a **tank**. This is an artificial pond surrounded by strong embankments, which is fed by underground culverts, or by a canal bringing water from the upper part of the watercourse; water may thus be collected in the tank to strengthen the stream below it.

There may be peculiarities of the locality which modify the mode of construction of tanks, but they are much less variable in this respect than dams.

Figs. 213 and 214 represent a tank which has been constructed at Wilgartswiesen in the Bavarian Palatinate. The reservoir *A* is constructed between the floating stream *t* and a small mill-stream *m*. It is surrounded by strong embankments (*d*, *d*), 14 feet high, and is fed by the mill-stream, which bifurcates from the watercourse above the reservoir, and is led along the hill-side with a gentle fall, so that at *a*, it is about 10 feet higher than the watercourse, which it rejoins after passing the mill *M*. There are sluice-gates at *a* and *b*, the former for admitting the water and the latter for its escape; *s*, *s* is a cart-road along which the wood is conveyed which is stacked at *h*, and there put into the stream. This tank holds 280,000 cubic feet (8,000 cubic-meters) of water, can be filled once daily, and takes 2 hours and 40 minutes to run dry, floating 42,000 stacked cubic feet (1,200 cubic meters) of firewood.

The embankments of tanks may be of earth or masonry, or half earth, half masonry, as shown in section in fig. 214. Here *A* represents the stone-masonry, *B* the earth-work, *a* the sluice-valve, *m* the feeder, and *t* the watercourse.

Tanks have been constructed at several places in Silesia, Franconia, the Palatinate, &c., and are utilized in summer for irrigating meadows and cultivated lands.

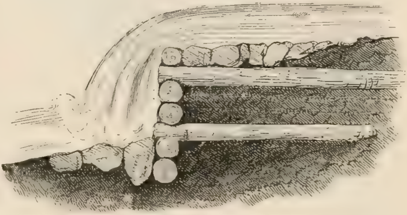
v. *Weirs.*

The works already described have for their object to increase the quantity of water in a floating-channel, but as soon as the accumulated water has run-off, the stream resumes its natural level.

Weirs, on the contrary, are constructed to raise the water-level permanently, and moderate its fall and velocity. They consist of a shallow dam erected across a stream, the top of which is either slightly below, even with or above the water-level, so that the water must more or less increase in depth behind the weir before passing it.

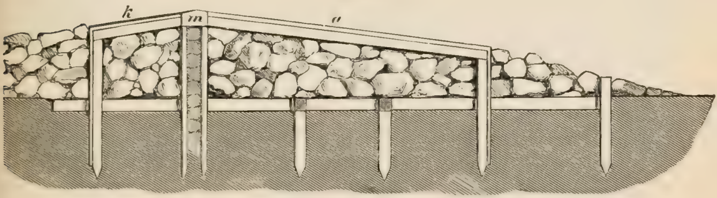
Thus we may have **ground-weirs**, below the surface of the stream, **over-flow weirs**, between the highest and lowest levels of the water, and **sluice-weirs** which are provided with gates; in the latter case, the quantity of water in the stream can be perfectly regulated.

Fig. 215.



All these three kinds of weirs are employed in streams used for floating; they are not only necessary to divert water to mills and irrigation-canals, when the water is used for these purposes besides for floating, but they also maintain a high permanent level of water in a floating stream.

Fig. 216.

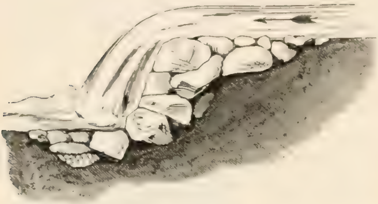


The construction of **ground-weirs** is very simple, they may be composed of a ridge of stones, a stem of a tree kept in position by piles, or a row of piles behind which sunken fascines or stones are placed.

An **over-flow weir** may be constructed either of wood or of stone; fig. 215 shows a section of a simple wooden weir with a steep declivity, and fig. 216, a weir with a gentle fall.

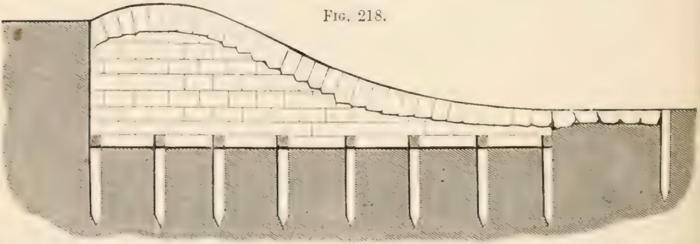
Stone-work is naturally preferable to wood in constructing weirs, and wherever coarse stones are available, a weir may be constructed as in fig. 217. Weirs constructed of hewn stone-masonry (fig. 218) are much preferable to rough constructions, and unless the water-course has a rocky bed, piles must be driven-in to serve as a foundation under the weir.

FIG. 217.



The efficacy of any weir is measured by the height to which the water rises behind it, and the distance back to the point where the stream retains its former velocity, or ceases to be slack-water. Hence, in order to thoroughly improve a stream for floating, a succession of weirs should be constructed from slack-water to slack-water, and in this way the average fall of the stream will be reduced, a very important point in floating.

FIG. 218.



The slower the current, the further back the slack-water extends; in sluggish streams, weirs may reduce the velocity of the stream too much for floating, and are only useful for diverting mill-streams from the main watercourse. Wherever, on the other hand, the current is rapid, it is evidently advantageous to keep the water back, as much as possible; for independently of the advantages of a moderate current, the banks and works to improve the floating are thus much better secured against erosion, and the depth of the stream is rendered much more suitable for floating, an important matter where it contains much gravel and boulders.

The most suitable places for weirs are narrow valleys between rocky banks, as in such places, the water cannot damage the banks of the channel and cause inundations, even when its depth is considerably increased.

In such places several consecutive weirs are generally required, so that the watercourse in certain cases becomes regularly terraced, with a succession of falls. As a rule, the number of weirs should be proportional to the rapidity of the current and the quantity of gravel and boulders in the stream. These weirs are not all constructed at the same time, but by degrees, as the space between any two of them becomes filled with silt and gravel, and therefore the necessity arises for a new weir.

Besides the above-mentioned weirs, others are also required wherever any side-channel leaves the main stream to supply a mill, &c. Booms for collecting the floating wood are also frequently erected on weirs. The more remote the point where the water from a side-channel is required, the higher must be the weir which supplies it.

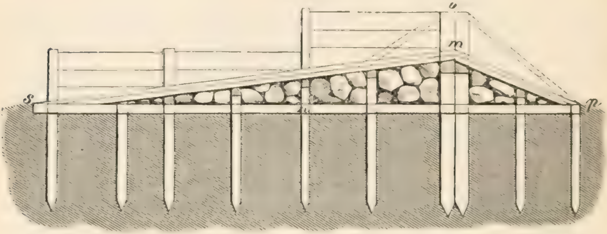
It is evident that sand, gravel and boulders accumulating behind the weirs constantly raise the bed of the stream, so that the water will in time overflow its banks unless they are sufficiently high. This is danger not only for the banks, but also for the wood which is being floated and tends to leave the stream and become stranded. If then a rush of high water follows, much damage may be done to the riparian properties, for which the manager of the floating will be held responsible unless he has taken proper precautions. In all cases, therefore, where such damage is to be feared, weirs should be furnished with sluice-gates which may be opened when there is danger of a flood.

Fig. 219 shows a section through the middle of a weir in which a sluice-gate is supplied (*m o n*) being the section of the weir, and (*o m*) the sluice-gate with a sloping base (*s m*), enclosed by wooden horizontal walls; this gate is closed when the water-level is at its ordinary height, but can be opened in floods.

More frequently, however, a ground-weir is erected with a number of sluice-gates arranged side by side, so that the whole weir may be removed in case of very high water, or to allow timber to pass.

It has been already remarked that certain works may be necessary to keep silt, gravel or boulders out of reservoirs; these works are merely weirs made of wattle-work or stone, across the small brooks which feed the reservoir, and thus the results of denudation of the hill-sides are kept from descending the water-course. In addition to these weirs, the ordinary measures should be adopted for fixing the slopes on either side of a mountain-torrent, and keeping it stocked with forest growth.

Fig. 219.



(b) Works for regulating the course of a natural Stream.

There is not a single watercourse which is naturally so suitable for floating timber but that it may be improved by some artificial works, to render the floating more regular and to avoid damage. In strong or weak waters there are always a number of hindrances: the banks may require securing; it may be necessary to remove obstructions from the bed of the stream by blasting, or otherwise; sometimes the current requires modifying, or bifurcations of the stream should be cut off whilst floating is in progress.

i. *Strengthening the Banks of Streams.*

Artificial works may be employed with advantage wherever the banks of a stream are too steep, or too sloping, or where the breadth of the stream requires modification. **High, steep** or **vertical banks** of a stream, if not of hard rock, get undermined and fall in, holes being formed in which the wood sticks; or the material of the bank may be carried away and form an obstruction lower down the stream. Wood which lodges against the bank becomes at length waterlogged, and may be lost. Hence, all bad banks require facing. Wherever the bank is composed of mere earth, a slope of 25° to 30° should be given to it, and it should be sodded or planted with willow-cuttings to give it firmness. If a current sets in against such banks they may be protected by wattle-work, a trench being dug along the bank, and a wattle-work fence constructed, and the interval then refilled with earth well rammed-in. The earth bank may also be faced with ordinary stone-masonry, or merely with large dry stones, and the trench filled with broken stones or gravel. Where stones are scarce, fascines may be laid parallel to the bank, secured by means of stakes, and covered alternately with stones or earth.

Fig. 220.

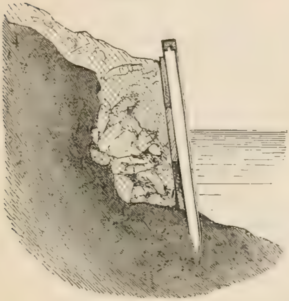
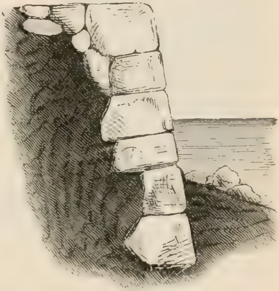
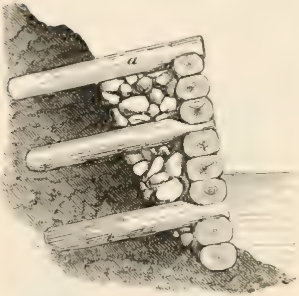


Fig. 221.



Other modes of protecting banks consist in a row of piles which are driven-in, in front of the place to be protected, and either bound with wattle-work, or planks or fascines fastened on inside them (fig. 220). Where wood is plentiful the walls may be of logs 4 to 6 inches thick (fig. 222), supported by stakes (*a*), and nailed together with long iron nails. It is, however, always better to employ stone-masonry for the purpose wherever stone is procurable; both to economise timber, and because the latter is not durable. Where stone is used for the purpose a good foundation must be supplied, as in fig. 221, to prevent undermining, and a slope of about one in ten should be given. As great a hindrance to floating as steep banks, are banks which are too flat, as the stream widens-out in such places, and tends to fall-off in strength, depth, and rate of current. The gravel and other material brought down from above accumulate in such places, forming shoals which the floating timber only passes with difficulty, and many logs become stranded. Improvements at such places have for their object to restrict the bed of the stream.

FIG. 222.



The simplest method is to drive-in a double row of piles as close to one another as the length of the logs which are floated, they mark-out the stronger water from the slack water near either bank. The piles are high enough to overtop the highest level attainable by the water, and the logs as they float down align the piles and exclude the dead water.

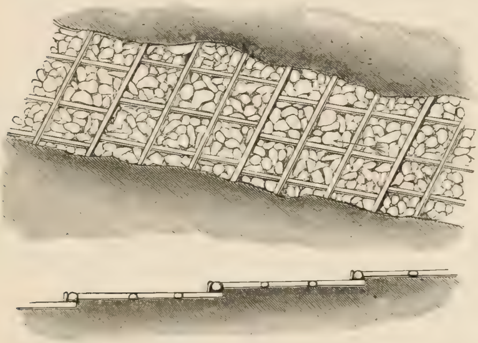
In some cases wattle-work is applied round the piles, other rows of piles are driven-in a few feet from the first rows, and the interval filled with stones, branches and sand. Finally solid parallel lines of masonry may be constructed, which are no other than dams running parallel to the stream, and united to the old banks by wings, and may be looked upon as artificial banks to the stream.

The top of these dams must then be of about the average level of the stream so that all flood-water passes over it, carrying with it silt and gravel which gradually fills-up the site of the slack water. Sometimes where there is an extensive track of slack water, it may be covered with a net-work of dams crossing one another, which gets filled with silt, &c.; if these dams are gradually raised as the spaces between them become filled, the slack-water may entirely disappear, and the lateral dams be no longer overflowed at high water.

ii. *Strengthening the Bed of the Stream.*

The bed of a stream much less frequently requires artificial improvement than the banks. This is, however, sometimes requisite, in the case of mountain-torrents with stony beds, and usually consists in blasting-away the rocks, and removing stones which might otherwise cause holes to form behind them in the bed of the stream, and thus catch the floating logs. The best time for these operations is the autumn, or whenever the water is lowest, and the stones removed from the stream may be utilized to improve its banks. It is, however, easy to do too much in the way of removing obstacles from the bed of a rapid stream: for if a floating-channel be freed from all impeding rocks and stones, which form so many natural weirs in its course, the stream often becomes torrential, and its banks may be broken and inundations or other disastrous consequences ensue.

Fig. 223.



Rapids may occur where the bed of a channel is narrow and steep, and the stream runs between rocks in passing from a higher stage in the valley to a lower one, and there is then likely to be difficulty in floating the timber. If in such places the bed be terraced (fig. 223), floating will be much expedited by making a network of logs which is filled in with stones. The blasting necessary in such a place is, however, so difficult to carry-out, that frequently the wood is landed and passed down a water-slide and placed again in the stream further on.

Careful paving of the bed of a stream is not unfrequent at openings from tanks, and to a certain distance inside the latter.

iii. *Rectifying the Floating-Channel.*

The channel of a mountain-stream usually winds considerably as soon as it approaches the plain, and its current is thus considerably reduced. The wood which is being floated has therefore to travel far, in order to pass over a comparatively short distance, and may become water-logged. Owing to the slight fall, inundations occur with every high water, and the banks of the stream are injured and much wood stranded far and wide.

Straightening the channel of the stream is then the best mode of obviating these dangers. The stream is straightened by making short artificial cuts between its bends and windings. Such a cut is generally commenced at several places between the points on the stream which are to be joined, the banks then serving as dams, until the channel is completed. It may even in such cases be worth while to make tunnels for the water to pass, as at Hals, near Passau.

Artificial floating-canals leading to a timber-depot are of the same nature as the above, and sometimes run from one river-basin into another.

The best known of these artificial floating-canals is that belonging to the Prince of Schwartzenberg, at Krummau, in Bohemia; it is 35 miles long, of which 600 yards are tunnels leading from the centre of the forests to the river Mühel, which flows into the Danube between Lintz and Passau, and brings down the yield of 35,000 acres of forest.

Whenever a canal is dug, levels must be most carefully taken beforehand; one in fifty is the best fall, though frequently unattainable. The canal just described has a fall of one in nine for a short distance, and one in the Bavarian forest a fall of one in five. In such places, the bed of the canal must be paved, or terraced, as already described.

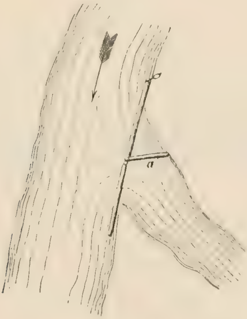
In the latter case, the upper section of the canal is only 4 to $5\frac{3}{4}$ feet broad, and $1\frac{1}{2}$ feet deep; it brings-down very large butts for the saw-mills. It is there constructed of blocks of granite, lower down its banks are made of wood, but in 1882 the floods proved too much for these wooden constructions. In the lowest section, where there is much more water available, the width of the canal is 10 feet.

In constructing such canals the chief point is to secure a good supply of water, and owing to the snowfall in mountainous regions this can generally be done. The line is then taken, as far as possible, through all adjoining mountain-streams, or it is supplied with water by reservoirs and dams.

iv. *Lateral Booms.*

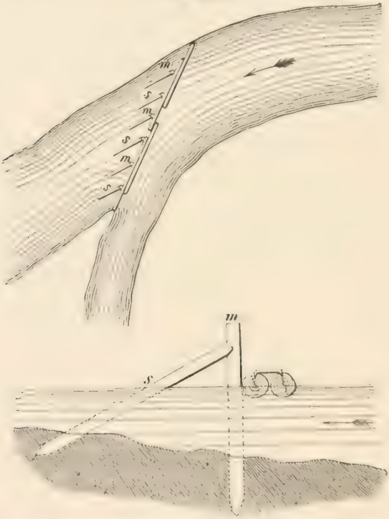
All streams used for floating have branches either natural or artificial, and arrangements must be made to keep the wood out of such bifurcations, or in certain cases, to conduct it into a side stream. To effect this, **lateral booms** either **floating**, or **fixed in** the bed of the stream, are required. A thoroughly dried spruce-log fastened to the bank of the stream by withes and floating in the water in front of the side-stream will often suffice.

Fig. 224.



Should the width of the stream be so great that this is not sufficient, a chain of two or more logs (fig. 224) attached together either by withes or iron rings, may be substituted. These are **floating booms**. Wherever a boom has to withstand a great pressure, as for instance where numbers of saw-mill butts are being floated, or the floating wood is being driven from the main-stream into a bifurcation, a **fixed boom** (fig. 225) should be constructed. In this case, piles (*m m*) are driven into the bed of the stream and are supported by props (*ss*). The logs forming the boom are then attached to these piles and close the stream.

Fig. 225.



One row of logs is often insufficient, and then two or more logs are fastened together and placed in front of the piles. Such booms will not, however, stop waterlogged wood; when there is much of this, a more complete boom is required, the construction of which will be described further on.

v. *Accessibility of the Banks of the Stream.*

Accessibility of the banks is another necessity whenever a stream is used for floating timber. The water must be accessible at least from one of the banks by a good foot-path, so that the workmen may be able to fasten logs to the shore, push off stranded logs, or land timber, and be able to move about expeditiously.

The only difficulty in lower mountain-valleys and level ground, is to come to terms with the riparian owners about sites for the construction of booms, &c. In the higher mountain passes, however, steep precipices often line the banks of narrow gorges, through which the stream passes, and the logs can be controlled by the workmen, only at great risk to their lives. Such gorges are especially common among limestone rocks, and form passes between the higher and lower stages of the valleys, the water falling in a series of cascades among large boulders and masses of rock. The floating wood is constantly sticking in such places, and a whole **sweep** of timber may thus be stopped. In order to prevent this mischance, the gorges must be made passable, and a pathway is often constructed with wooden galleries supported by numerous iron bars and wooden beams let into the rock, and connected with one another by steps cut in the rocks, and by ladders.

3. *Booms.*

Booms are constructions intended to arrest or divert the passage of all floating wood at a fixed point in a stream. All floating timber is thus stopped or diverted by the boom, and where large sweeps of timber come down, the boom has to resist considerable pressure and must be very strongly constructed; its site also should be favourably situated for the purpose in view.

Booms, therefore, vary from those of the simplest nature to colossal structures costing thousands of pounds. Most of these booms are constructed by ordinary woodcutters or floaters, who from long experience in the work frequently show great ingenuity; some of them may even be classed as engineers. But for the very reason that the nature of booms depends on local conditions, no constructions are more varied, and hardly any two booms are alike. In the following paragraphs, therefore, some characteristic forms of booms only will be considered.

(a) **Mode of construction.**—There are three essential points in the construction of a boom, the supports, the horizontal bars which stop the sweeps of timber, and the grating of rails which surmounts the boom.

Booms may be divided into two classes according as the grating is vertical, or oblique, the largest and most important belonging to the latter category.

FIG. 226.

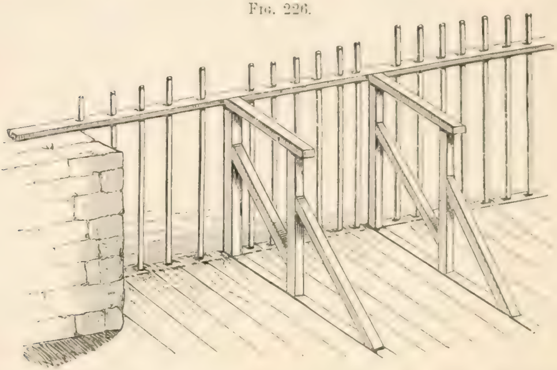
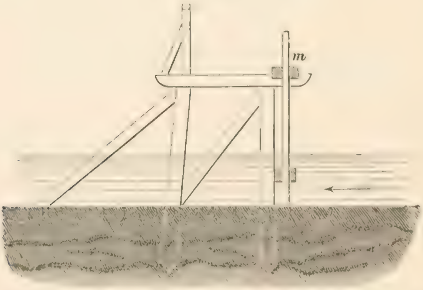


Fig. 226 represents a simple form of wooden boom with a vertical grating which has to resist a moderate pressure only; fig. 227 shows the section of a support to this boom and (*m*) the grating and horizontal bars. Wherever in mountain-streams rocks occur on which the grating may be supported, they may be utilized as supporting piles for the boom; but if such natural

FIG. 227.

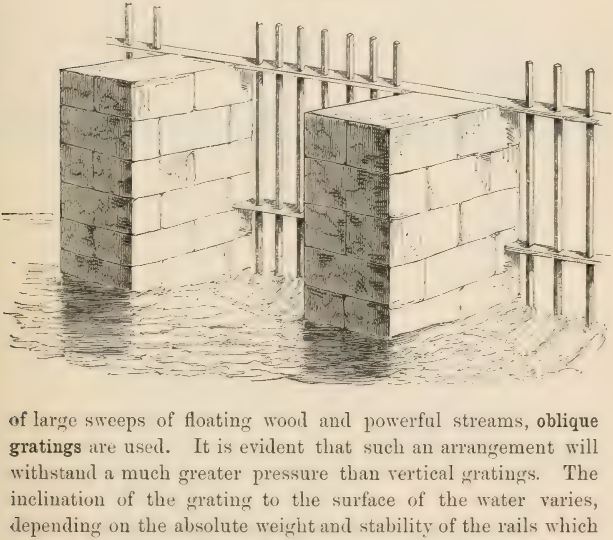


supports are wanting, and the pressure of the sweeps of timber is great, masonry-pillars must be erected for the purpose (fig. 228).

The **horizontal bars** are constructed of large balks of timber, which are bored through in order to allow the rails of the grating to be inserted; or they are composed of three balks, the middle one perforated to support the grating. The lower bar is frequently placed at the water-level (fig. 226) where it is best preserved.

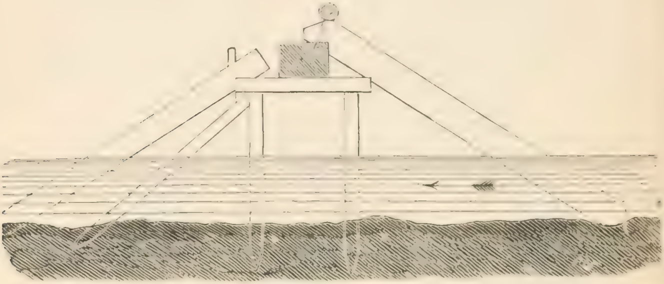
In the case of large booms required to withstand the pressure of large sweeps of floating wood and powerful streams, **oblique gratings** are used. It is evident that such an arrangement will withstand a much greater pressure than vertical gratings. The inclination of the grating to the surface of the water varies, depending on the absolute weight and stability of the rails which form the grating. Where these rails are large—in large booms they often attain lengths of 20—25 feet and a thickness below of 8 to 10 inches—the inclination of the grating may be 60°, but otherwise it is placed more obliquely, say, at an angle of 25° to 30°.

Fig. 228.



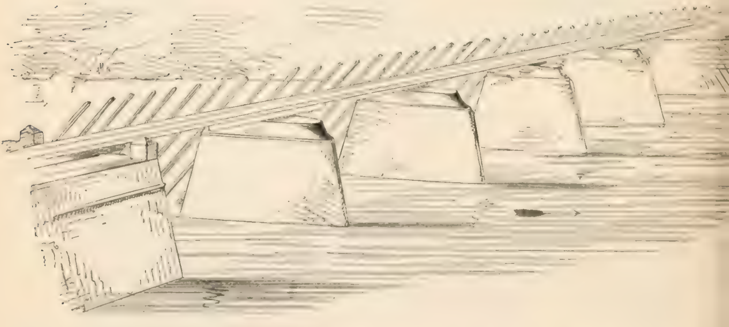
The rails of the grating are always round pieces, barked spruce or larch, with their thicker ends in the water, and they rest without any support on the bed of the stream. In front of them, floating spruce stems are placed to take the shock of the floating wood from the grating. Where the stream is broad and the grating long, supports are also necessary, their simplest mode of construction being shown in fig. 229.

Fig. 229.



The supports of large booms require, above all, a solid foundation; in the case of wooden supports, piles are driven sufficiently deep into the firm (rocky) bed of the stream, and when there are

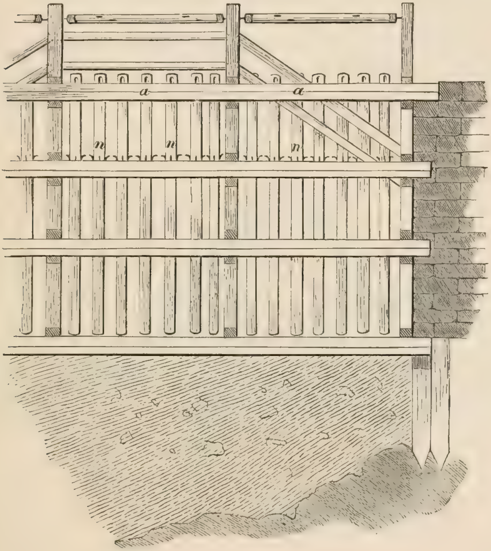
Fig. 230.



masonry-supports, by a firm foundation of piles, in case a rocky base cannot be reached. Fig. 230 represents a large boom over the river Regen, at Regensburg; in this and other large booms the supports are similar to those used for large bridges, and are arranged with their longest sides parallel to the stream so as to offer as little resistance to it as possible. Of a similar construction is the large boom at Baden near Vienna, that over the Ilz at Passau, the boom nearly a kilometer ($\frac{5}{8}$ mile) long at Brixlegg and other large booms.

What enormous pressure such booms have to support, especially in floods, may be easily imagined from the fact that floating

Fig. 231.

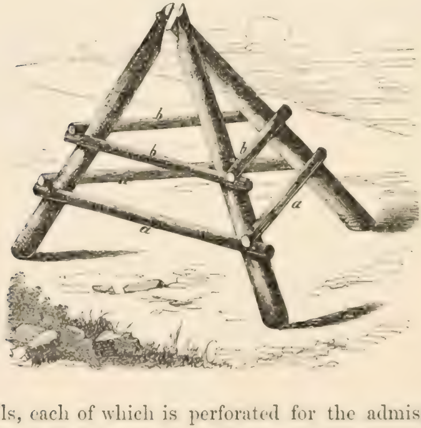


timber often accumulates behind them to a height of 15 to 20 feet, and sometimes even overtops them. In such cases, as has been already remarked, not only must the construction of the boom be of the strongest possible character, but also the locality must be specially adapted for it.

In the case of many booms, with either vertical or oblique gratings, the latter are placed *in situ* only during the floating season, and for the rest of the year are removed and kept in sheds on the river-banks. This cannot always be done, when the grating rails are very large and weigh several hundredweights each, but even then, part of the grating must be removed if the stream is to remain navigable, or passable by rafts of wood. In such cases, the rails are provided with strong iron rings so that they can be raised by means of hooked poles and placed on the horizontal bars, and on a planked footway constructed behind the latter.

Water-sawmills always require booms to keep out the floating wood which is intended to pass beyond them. Such booms must be constructed so that part of the grating may be readily removable and allow entrance for the butts which are to be sawn. The grating is, therefore, frequently provided with the arrangement shown in fig. 231. The hooks at (*n n*) are for the removal of the rails, each of which is perforated for the admission of a wedge to keep it when raised in position, the wedges resting on the bar (*a a*).

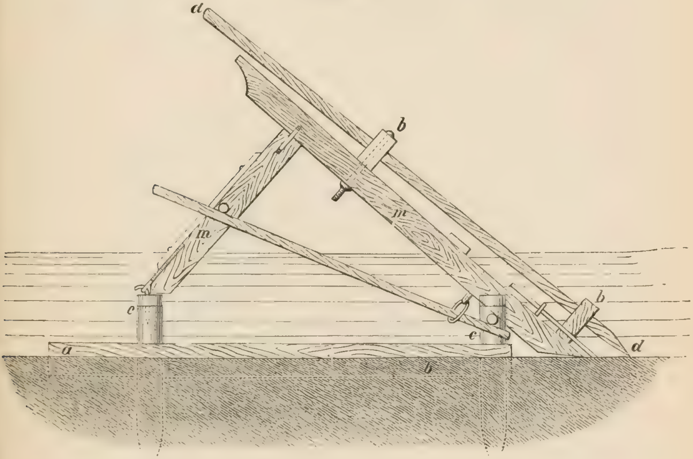
Fig. 232.



Besides the above usual kinds of booms, special local booms, such as **trestle-booms, portable booms** and **booms with gabions** are in use, of a cheaper and simpler mode of construction. They are chiefly used for temporary floating, or in the case of streams subject to such high floods that the construction of more elaborate and expensive booms is not advisable. They are therefore, re-made every floating season, and then broken-up, and are chiefly prevalent on the south side of the Alps, in Savoy, the South Tyrol, Carinthia, and other districts.

The essential feature of a **trestle-boom** is a three-legged trestle (fig. 232). These trestles, strengthened by the transverse pieces (*a a*), are placed in a line across the stream so that one foot of each projects somewhat over the foot of the trestle next to it, and the tops of all the trestles are about the same height above water-level. Thus different sized trestles are required according to the depth of the water. In the case of large trestle-booms over strong streams, a second row of trestles is placed behind the first to strengthen it, one of the feet of the second row crossing the feet of those in the front row. This crossing of the feet of the trestles strengthens the boom in a very marked way.

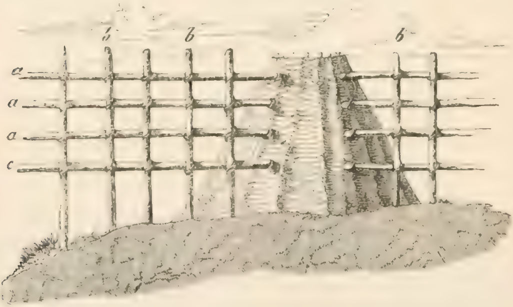
Fig. 233.



After all the trestles are in position in the water, the bars (*b b b*) are nailed on to them; they are intended to support heavy logs with which the trestles are loaded, to add weight to the boom and render it firmer. As the trestles are not imbedded in the ground, but only rest on it, they would not withstand the force of the stream if the trestles were not heavily weighted. Further weight is added by placing stones and boulders above the logs which rest on (*b b b*). Supports for the rails are then nailed on to the trestles, and the rails fastened to them with withes, and floating placed in front logs of the rails.

Portable Booms form another class which may be erected and removed at pleasure, but their mode of construction varies considerably. Fig. 233 represents a section of such a boom with a permanent base, which is used in streams where sudden floods occur, as in lower Austria, the rivers Ziller, Gail, &c. The fixed base is composed of a beam (*a*) and piles (*c c*); on the latter the trestle-beams (*m m*) rest, and the grating-rails (*d d*) are supported by pieces (*b b*) which are bolted to (*m*). Another kind of portable boom is used in Nadworna in Galicia, in which three twisted wire ropes are stretched as tightly as possible one above the other, and supported by trestles at distances of 30 feet apart.

FIG. 234.



Another kind of boom is formed of **gabions** (fig. 234), as used in Venezianisch and other places. Here, instead of wooden or stone pillars, gabions of basket-work filled with stones are used, which support the horizontal bars and the grating-rails. The gabions are placed in a line across the stream at distances of 5 to 15 meters (16—48 feet) apart, according to the strength of the stream, and are tall enough to be above the highest water level; their height varies, therefore, with the depth of the water in which they are placed. Planks are then placed from gabion to gabion, forming a footway, and stout poles (*a a a*) are bound to the gabions by means of withes. The grating-rails (*b b*) are then bound to (*c*) outside the water, and let down into it from the footway, till each rail rests on the bottom of the river. The several rails are then bound by withes to (*a a a*), and along the grating floating logs are placed.

These gabions have the advantage of costing little, of being erected in a short time by the floating-gang and of being easily repaired. At the same time, they are not durable, and are often overthrown by heavy floods, to which they offer a great resisting surface. They are specially adapted for small temporary sweeps of floating timber, especially on unimproved mountain-torrents.

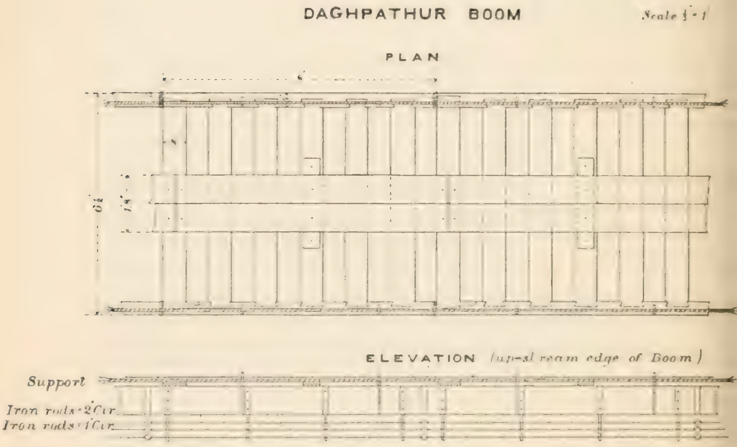
Finally, **floating booms** must be mentioned. They consist for the most part of spruce-logs which are united at their ends by iron rings and fastened together in sufficiently long chains. These chains of logs are fastened at one or both ends, and float on the surface of slowly flowing streams, on which floating is done only occasionally. In order to give them a greater power of resistance, some of the logs are anchored to the bottom of the river. In spite of this, however, they cannot resist a sudden flood, as has been often experienced, in the breaking of such booms, especially if the stream is fairly strong (the river Inn).

[In the river Jumna, at Daghpathar, a boom is placed at a point where the river is 120 yards broad. It consists of two portions, a raft 354 feet long, constructed of railway-sleepers as shown in fig. 235. It is fixed at one end to a rock on the right-hand side of the river, and kept obliquely inclined towards the current by wire ropes anchored to the other bank. This portion of the boom is placed in the full current of the powerful stream. From its other end extends a line of logs fastened end to end by a wire rope, and 910 feet long. The floating sleepers are stopped by the raft-boom, and then float along the line of logs into slack water, when they are easily caught by men swimming on inflated buffalo-skins, and landed.

The construction of the raft-boom is as follows:—

Two broad-gauge sleepers are placed 6½ feet apart and with their broad face vertically downwards; transversely to these and dovetailed or merely let-in, are placed at intervals of about one foot-meter-gauge sleepers with the broad face horizontal. In the centre are two planks placed longitudinally and serving as a foot way. A wire rope runs along each side, and is firmly fixed to the broad-gauge sleepers. This is to give the boom flexibility against sudden strains. Below the sleepers are three iron rods one inch in girth supported by bars two inches in girth from the broad-gauge sleepers.

Fig. 235.



Drawn by A. G. Hobart-Hampden.

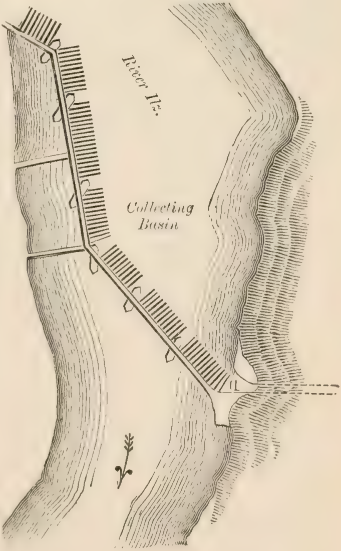
This boom cost Rs. 1150, including Rs. 500 for wire ropes which last for many years; it is annually removed before the July monsoon, and replaced in October. About 400,000 sleepers and scantling are stopped by it annually and made-up into rafts at Daghpathar.—Tr.]

(b) **Modes of using Booms.**—According to the strength of the stream, the purpose for which they are erected, but above all on account of their suitability for any particular locality, various kinds of booms are used. Here, in the first place, a distinction must be made according as the booms are used, either to stop all the wood floating in a stream (**terminal booms**), or to divert it into a side-channel (**lateral booms**), and it must be considered, secondly, what steps may be taken to reduce the pressure on booms and prevent them from breaking.

i. *Terminal Booms.*

Terminal booms, intended to stop all the wood floating in a stream, are erected either **transversely** or **obliquely** across a stream, the former being termed **straight** and the latter **oblique booms.** Booms may run in a broken line, or be arranged so that a quantity of floating wood may be collected and taken away from the boom.

Fig. 236.



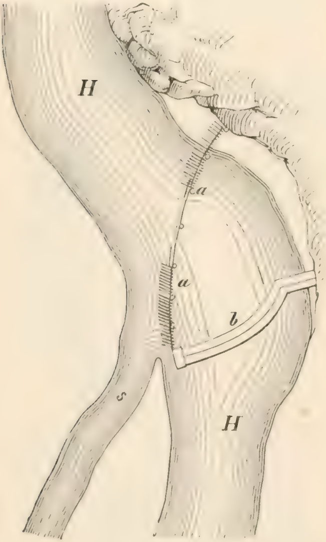
Straight booms are chiefly found on streams with a slight fall and where sudden floods are not to be feared. They have to resist severe pressure, and wherever large sweeps of wood are floated should be strongly constructed.

Oblique booms are commoner both in the case of **lateral and terminal booms**, they have naturally a greater length in proportion to the breadth of the stream than straight booms, and the longer they are, the better able are they to withstand the pressure of the floating wood and floods. Most booms are not straight, but have a broken line of contour; and many booms, and some of the most important ones, collect and retain for some time a large quantity of the floating wood. The boom across the river Ilz near Passau, built as in fig. 230 and a plan of which is given in fig. 236, collects over ten thousand saw-mill butts, and allows for their being continually removed by the underground channel (*a*).

ii. *Lateral Booms.*

These booms are intended to divert floating timber into a side channel, and are long and oblique.

Fig. 237.



In powerful floating-channels, a terminal boom cannot usually be laid across the main stream without danger of being broken. In such cases, therefore, a side channel is diverted from the main stream and the sweep of timber conducted into it, the main stream being barred by a boom. Fig. 237 is a long lateral boom, only closed in the middle by floating logs. *H* is the main stream; *s*, the side-channel, lower down in which the terminal boom is placed; *b* is a weir diverting water into *s*. As in this case the pressure of the sweep of wood and of the stream is divided between two booms, neither of them need be very strongly constructed. This is the chief advantage of leading the floating wood into a side-channel. Where a natural bifurcation of a river does not exist, an artificial side-channel is frequently constructed with advantage: if, then, the lateral boom is supplied with a strong weir, or, if possible, with a sluice-weir, the supply of water to the side-channel may be regulated at will. On this general principle are founded all the better kinds of riverside sawmill timber-depots, which will be described further on.

By supplying booms with sluice-gates, they may be considerably improved; but this necessarily pre-supposes sufficient strength to withstand the pressure of the wood and water. Sluice-gates are specially valuable in the case of large booms with masonry supports. By regulating the supply of water, the front of the boom may be more uniformly covered with floating wood, so that when the sluices are opened the greater part of it may become stranded, or can easily be brought to land. In the case of long booms, it is highly advantageous by opening first one sluice-gate and then another, to drive the wood in front of portions of the boom hitherto free from it; and, finally, by opening all the sluice-gates to bring in the tail of the sweep of the wood.

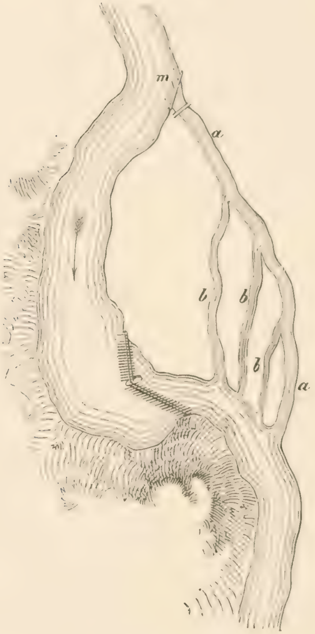
iii. *Reduction of the Pressure on a Boom.*

Attempts should be made in every possible way to reduce the pressure on a boom, and this object may be secured in various ways by constructing **booms on weirs,** by means of **channels for waste water, channels to remove sand, sluice-gates, &c.**

Lateral booms are generally placed on a weir, which supports part of the water-pressure and reduces the fall of the stream and the pressure on the boom. Nearly all large booms which are intended to strand the wood, or to serve as lateral booms, are of this nature. **Channels for waste water** are artificial cuts which branch-off from the main stream above the boom, returning into the stream below it. A certain portion of the water is thus led away from the boom, which has, therefore, less pressure to withstand. Fig. 238 represents such a channel, which is supplied at its outlet (*m*) with a lateral boom and sluice-gates and subdivides below into several branches (*b*, *b*, *b*). If the terminal boom were also in a side-channel, which has besides the advantage of a weak current, its utility may be further increased by smaller channels taken from above the boom and returning into the other below it.

Booms in streams which bring down boulders and gravel have, besides the force of the current and of the floating wood, to withstand the pressure of the sand and boulders. Wherever, therefore, the fall of the stream is considerable, it is usually sufficient to place the boom out of the main current by allowing surplus water to pass off by a side-channel; or, when the boom is in a side-channel, a deep and steeply inclined cut, termed a **sand-canal**, is made in the latter to carry the sand and boulders into the main stream. Fig. 239 shows the floating-channel (*s*, *s*), which bifurcates from the main stream, *H*; (*m*, *m*) form so many cuts between strong, solid masonry walls, which may be closed by lateral booms and sluice-gates; (*a*) is the sand-canal, which at (*d*) is only half a meter deeper than the rest of the floating channel, but deepens gradually towards (*p*). The boulders which accumulate in (*d*, *p*) are passed through a temporary opening (*p*)

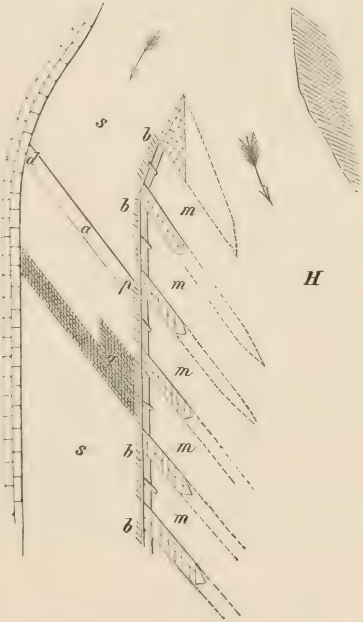
Fig. 238.



and the corresponding sluice-gate in the lateral boom, and pass along *m* into the main stream *H*.

Simple sand-canals can only be opened for the passage of silt, &c. whilst floating is not in progress. In order to free a floating-channel from these accumulations during the floating, they

FIG. 239.



may, as at (*q*) (fig. 239), be covered with a wooden lattice-work (fig. 258) constructed at the bottom of the floating-channel (*s*). Besides this method, double booms may be used, which are erected the one close behind the other, and the silt and boulders are admitted into the interval between them by opening the first boom and then passed through the second boom, so that always one of the booms is ready to stop the floating wood. In order also to expose the bed of the stream in front of a boom and then strand the timber, deep culverts with sluice-gates may be made and opened to pass the water under the boom.

(*e*) **Further Details regarding Booms.**—In the preceding paragraphs, a distinction has been made between **lateral** or **terminal booms,** but the latter may be of several kinds. Every boom, whatever its dimensions, which catches floating wood at a timber-depot is a **principal boom.** Owing to certain conditions of a locality and want of sufficient room, it is not always possible to supply every river timber-depot with a principal boom; or the risk cannot be incurred, in the case of numbers of saw-mills situated along a stream, of entrusting the supply of the thousands of logs they require for their annual work to one boom only, which is always liable to be broken. In such cases, **subsidiary booms** are used in order to ensure a supply of wood for all the saw-mills.

For this purpose narrow parts of the stream are selected, confined on either side by rocks, and booms are here erected with moveable gratings, from which the wood can be again despatched down-stream in small sweeps to the different saw-mills or timber depots.

Not unfrequently a stream is broken-up by booms at not very long intervals; this is generally for charcoal-burning, in order to land the wood required where permanent charcoal-kilns are maintained; or each forest owner or principal wood-merchant has his own boom, in order to collect his own wood and float it separately from that of other owners to the principal boom; or the saw-mills situated along the stream have each its special boom, provided with passages to allow extraneous wood to pass through them.

Subsidiary booms are sometimes erected in strong streams below the principal boom, where, owing to occasional floods, there may be danger of the latter breaking. Wherever floating timber is rafted, or passed in lines of logs across a lake, most of the water-logged wood would enter the lake and sink to the bottom without possibility of recovery, were not a boom stationed at the point where the stream used for floating passes into the lake.

4. *Method employed in Floating Wood.*

(a) **Season for Floating.**—The more quickly a sweep of wood is floated and reaches its destination, the better is the business of floating it conducted. For this purpose, a steady and ample supply of water is necessary. The melting of the mountain snow in spring brings most water into European streams, and spring is therefore the chief season in Europe for floating timber. At this season all the brooks and springs which flow into the floating-channel are swiftest and most buoyant, owing to the coldness of the snow-water. All reservoirs and tanks can thus be readily filled, and the largest possible volume of wood brought down in the shortest possible time.

The weaker the floating-channels, the greater care must be taken to utilize, for floating, the critical period in the spring, after the snow has disappeared. Although in mountainous districts with heavy rainfall, the period of melting snow brings down sufficient water into the streams for floating purposes, floating is frequently protracted into the summer months, and then requires all the help of an artificial supply of water. In such cases, the forester will direct his attention to the summer rains for supplying his reservoirs. It is evident that the whole prosperity of the saw-mill industry depends on a choice of the right moment for floating the wood.

Floating on large streams permanently well supplied with water, and on smaller streams supplied from lakes and reservoirs, may continue throughout the year. In such cases it is preferable to float in the autumn, when floods are less to be feared than during the spring. [This is the case in India with rivers such as the Jumna, where the principal boom is always removed from May till November, when the river is swollen with snow-water and water from the summer monsoon.—Tr.] In high mountain-regions floods occur late in the spring and in the early part of summer, and it is therefore in several districts safer to choose midsummer (in the Italian Alps, late autumn) for floating, especially where protective works against floods are wanting.

Small reservoirs may be filled three or four times in a day, but large ones may require several days to fill.

(b) **Nature of the Wood to be Floated.**—Saw-mill butts and the better kinds of firewood (split billets, and large round pieces) are floated. [In India also railway-sleepers and other scantling.—Tr.] The butts are first barked and trimmed free from knots and stumps of branches, and frequently rounded at both ends to guard against splitting. Firewood and charcoal-wood is either floated in round butts (twice the length of the ordinary billets) which are sawn and split into billets after landing at the booms, or in split billets.

Whether it is preferable to float butts or split billets, depends on circumstances; butts require a stronger current, but are less liable to breakage by boulders, &c. in a floating-channel, than billets, which require improved channels with a moderate current. It is evident that light coniferous butts are more easily floated than broad-leaved ones; also, wherever carbonisation is effected with round pieces, as in the Alps, they must be floated in that form. Butts for saw-mills require stronger water than firewood, lengths of 3 to 4 meters (10 to 13 feet) being most suitable, although in Sweden, butts are floated up to a length of 7 meters (23 feet). It is often difficult to float heavy butts, especially of silver-fir, unless they have been previously dried.

The most important operation, before floating is undertaken, is that of drying the wood, for the amount of water-logged wood varies inversely with the comparative dryness of the wood when launched. Wood felled in the growing season dries more quickly than winter-felled wood, and is therefore more easily floated. It is indispensable to thoroughly dry the butts which are to be floated for long distances.

It is especially requisite, from a consideration for the quality of the wood, that butts felled and barked in the summer should immediately after felling be removed from the felling-areas, and deposited in airy depots, in order to become thoroughly dried. If, then, during winter wood is brought to the side of the floating-channel, not only does the drying process improve its quality, but also facilitates the operation of floating.

(c) **Conservancy of the Floating-Channel.**—Before the wood is thrown into the floating-channel, a thorough knowledge should be formed of the condition of the latter, and of the different works which have been constructed to improve it. For this purpose, an inspection should be made, if necessary with the co-operation of riparian landowners, owners of saw-mills and other hydraulic works along the floating-channel; enquiry should then be made into all claims of compensation for damage done by the floating-gang, in order to prevent unfair excess in its amount, and, if necessary, these claims should be settled by arbitration or the Law-Courts. This inspection should, if possible, take place in fine weather and when the water is clear, so that the bed of the stream may be seen.

As this inspection serves for settling excessive claims for compensation, it should be made as soon as possible after the previous year's floating is over; it is also useful to assist the forest manager in deciding about the suitability or defects of any of the works along the water channel. It is clear that repairs to these works cannot be postponed till shortly before the floating season; they must be done, together with any new indispensable works, when the water is low in summer or early in the autumn. The same proviso holds good for clearance of the floating-channel, which is required both in its lower course, where the current is sluggish, and also in its upper course, among rapids and boulders. Whenever it is necessary to expose any portion of the bed of the channel for this purpose, arrangements should be made to procure the necessary stoppage of all mills, &c. for the purpose. The days on which the stream is allowed to run dry are either fixed by law, or secured by compensation to the mill-owners, owners of works established on the stream before it was used for floating being alone entitled to compensation.

(d) **Conduct of the Floating-Operations.**—During winter and early spring the wood is brought to the side of the floating channel, and placed on its banks in loose stacks. Should there be, as is frequently the case, a narrow valley just below the reservoir dam, so that the wood cannot be washed away laterally, it is frequently placed on the dry bed of the channel; the pieces of wood should then be scattered, so that when the dam is opened a jam may not arise.

If, then, all the wood of most of the felling areas has been brought down, the efficiency of the floating-channel and its works has been ensured, and everything is ready at the timber-depots below for the reception of the wood, the first sweep of wood may be sent down at the right time. A careful choice of the latter is of great importance, and is a matter of days, even of hours. A commencement should always be made in the most remote and weakest of the subsidiary streams, so that the sweep of timber passing through it may come down as soon as possible into the main stream, where progress is not so dependent on the period of the highest floods. Hence, a distinction may be made between **subsidiary sweeps** of timber and the **principal sweeps.**

Wherever the cost and difficulty of subsidiary sweeps is out of proportion to their utility, attempts should be made to substitute sledging for floating, as is already being done in the Alps. In other localities, as in the Palatinate, only subsidiary sweeps are attempted, the wood being floated right up to a railway.

Before the sluice-gates are opened, and floating the subsidiary sweeps is begun, the quantity of the wood to be launched should be proportioned to the quantity of water in the reservoir and the strength of the boom, otherwise there will be danger of the tail of the sweep being left stranded, or of the boom being broken, if a flood should occur. Due consideration having been given to these points, the sluice-gates are opened, and after the preliminary flooding, the strength of which depends on the amount of impediments there may be in the floating-channel, the floating-gang commence throwing the wood into the stream. As soon as most of the water has left the reservoir, the gang stop launching the wood, so that the residue of the water may have its effect on the tail of the sweep and carry it away. As soon as the reservoir is empty, the dam is closed again in order that a fresh supply of water may be collected.

In the case of floating-channels which cannot be flooded by a considerable body of water, but only by a moderate supply, from fear of damage to their banks, it is the duty of the forest guard in charge of the reservoir to be careful not to supply more water at a time than is absolutely necessary. He will easily learn by experience for how many miles down the water from his reservoir can flood the floating-channel sufficiently, and how long the sluice-gates should be kept open to ensure a proper supply.

The wood is now carried down by the flood from the reservoir, and the best, smoothest, well-dried wood keeps at the head of the sweep, whilst inferior knotty wood and heavy butts gradually lag behind to form its tail. However well the floating-channel may be regulated, hindrances will arise whenever the wood enters a difficult place and blocks the way for the rest of the sweep, and may thus block the channel and drive the flooding water over its banks, or in the most favourable case allow it to run away uselessly. In order to prevent such a mischance, the sweep is accompanied by some men of the floating-gang, and men are also placed beforehand at any places along the channel where a block is to be feared, so that with their hooked poles they may push off all pieces which are jammed. It is necessary for overseers to supervise these men, and hence, a fairly good pathway must be provided all along close to the side of the channel (*vide* p. 384).

Although in the case of floating split firewood billets in well-regulated channels the work may be very light and easy, it involves extremely hard labour and danger to life in the case of saw-mill butts coming down from high mountain-regions.

Wessely thus writes in his excellent work about the Austrian Alps:—"The mere releasing a jammed mass of logs is a formidable undertaking. In order to save labour, it must be set free from below; a single crossed log often detains the whole pile of timber; this is at once recognized by the woodman, who drags it out, but he has hardly done so before all the logs come crashing down on him and roll thundering down the flood. If he does not succeed by skill and good luck in jumping aside, it is all over with him. There is much *jodeling* over the break-up of a jam, but only too often does the mass of timber fall on the daring man who ventures upon it, and but rarely is he fished seriously injured from the flood by the help of a hooked pole. In gorges, and there are such 50 fathoms deep, a man is let-down by a rope into the foaming torrent, and must actually stand on the heap of wood. If his comrades do not draw him back at the very moment when the logs are set in motion, he will be hopelessly carried down with them."

In the Bavarian gorges, as has been already stated, this dangerous work is assisted by means of galleries let into the rocks.

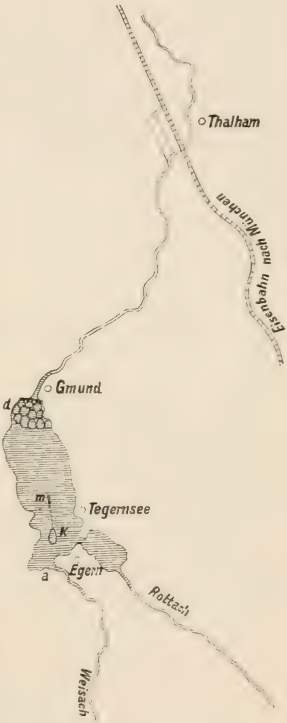
Once the wood has been carried down to the main floating channel, the sweep of logs now becomes the **principal sweep** and floats on to the boom. In the case of larger brooks and rivers, the wood is left to itself, but if the water is shallow, assistance must still be afforded from reservoirs.

Usually the principal reservoirs of the subsidiary streams, if they help one another, and flow one after the other into the main stream, greatly assist in floating the principal sweep. Experience shows how long a flood from a reservoir takes to reach the main stream, and this period is chosen for the interval between the opening of the sluice-gates of neighbouring reservoirs. In long and weak floating-channels the reservoirs of the tributaries are not sufficient to maintain high water in the main stream, and in such cases reservoirs should be provided along the main channel. In floating a sweep great care must be taken that the reservoirs on the subsidiary and main channels work well together. As soon as the reservoirs of the tributaries are again full, more wood is launched and floated, and this continues daily until all the wood has been launched and has gradually reached the booms, when it is either collected in tanks, or taken out of the water, according to the nature of the boom.

Whenever a floating-channel passes through a lake the wood must be stopped as it enters the lake and towed across it. Everywhere for this purpose light coniferous logs are used, which are bound-together by iron rings, or withes, and thus form a long floating girdle which may be used to surround the wood in the lake and keep it together. With this object, the chain of logs is placed in an arc before the entrance to the lake, and as soon as it has enclosed as many logs as possible, its ends are joined. The raft thus formed is then borne to the other end of the lake, either by help of a favourable wind, by beasts or manual labour ; the chain is then opened and the logs floated further down the stream.

Favourable weather is necessary for this crossing to be effected ; storms not unfrequently break-up these rafts and scatter the logs over the surface of the lake, so that great expense is incurred in collecting them. On the Pacific coast of North America, and also in Norway and Sweden where it is quite usual to convey logs in those temporary rafts, screw steam-boats of light draught are attached to them, or they are dragged forwards by ropes attached to windlasses on boats anchored in the lake. This practice is in vogue on the Tegern lake (fig. 240). The wood floated down the river Weisach runs into the lake at (*a*), is bound into temporary rafts and drawn by the anchored boat (*m*) to about the middle of the lake, whence the mountain-wind blows it to (*d*) at the other end of the lake. The rafts which are collected there are opened one by one, and the wood floated on the Mangfall river to the timber-depot at Thalham, where it reaches the rail-road to Munich.

Fig. 240.



(e) **Completion of the floating.**—All the wood which has been launched by no means floats steadily down to the boom. Frequently, a considerable percentage of the launched pieces remains on rocks, shoals, and other inequalities of the channel, sticks under its banks, or remains floating in the still water near the banks. All this wood should now be set free, drawn into the stream, or else placed so that it may be caught by the next flood from a reservoir, or natural flooding of the river, and carried down to the boom; this operation is termed **after-floating.** This work, which is often protracted well into the summer, is usually commenced from up-stream, but if after all the reservoirs are exhausted, or owing to unfavourable weather the water in the channel is very low, only a portion of these stranded logs can be floated before the succeeding year. In such a case it is better to begin from the lower end of the channel.

During the after-floating, but chiefly when a certain amount of progress has been made in floating off the tail of the sweeps, the sunken wood should be fished-up, most of it occurring at the lower end of the channel.

The quantity of sunken wood depends on the amount of drying to which the wood has been subjected before being launched, the condition of the floating-channel, and above all the nature of the banks, the fall and buoyancy of the water, the length of the channel, and the species, nature, and size of the floating pieces. Round pieces sink more readily than split pieces, and branches of spruce and silver-fir being much heavier than their stems yield a greater percentage of sunken wood.

The workmen use the hooked pole to spike the logs or billets and draw them to the bank. Fine weather is required for this work, and clear water, so that the bottom of the stream and all sunken wood may be seen. The wood is collected daily and piled in loose stacks on the bank of the stream, and when dry, it is either transported by land, or sold.

As soon as the annual floating is over and the sunken wood collected, a report is drawn-up by the same commission which acted before the floating. In this report all legal damages are entered which neighbouring properties may have suffered from the floating operations, all legal compensation being paid. This opportunity is also taken to prepare a list of any damage which may have been done to the floating-channel or the works attached to it, so that they may be repaired in the ensuing summer.

SECTION II.—RAFTING.*

Rafting is distinguished from floating by the fact that the wood is no longer in single pieces, but is bound-together into rafts. A quantity of wood firmly bound together is termed a **raft-section**, and a number of sections form a **raft**.

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* Although rafting is rarely done by the forester, yet the rafts are made-up with withes and cross-pieces which he has to deliver. In certain districts, logs are only measured when they are bound into rafts, and frequently a floating channel is also a rafting-channel, and has to be prepared with that object in view. 40 per cent. of the 14,000 kilometers (8750 miles) of German rivers are used for rafting.

1. *Rafting-Channels.*

In order that rafting may be possible, it is generally necessary that the water in a stream should flow uniformly and gently, with only a slight fall. In well-regulated rafting-channels a smaller head of water is required than in mere floating-channels, but the depth must not be less than 2 or 2¼ feet. Although rafting may be done more favourably on the lower courses of streams and large placid rivers,* yet higher mountain-torrents are sometimes thus utilized. In such cases, however, where the channel is full of rocks and boulders and has a considerable fall, a larger head of water is required than for floating, for unless the rafts are carried over all obstacles in the water, they will be stranded and broken-up.

In the latter case, therefore, artificial supplies of water are requisite, and both reservoirs and weirs placed along the stream are employed to increase the head of water. The latter are either sunken weirs with a long wooden wall in the middle of which there is a passage which may be closed, or stone overflow-weirs are used.

Reservoirs are not so valuable for rafting as for floating, as they do not concentrate the water in a certain part of the rafting channel. On the other hand, this may be done effectively by placing weirs at short distances apart along a channel, when the water can accumulate between any two weirs to the height required by a raft.

Wherever the sections and rafts are made-up in powerful streams, a side-channel or basin is required wide enough for the logs to be turned and placed alongside one another. In smaller streams this is best secured by constructing weirs at places with shelving banks. In the upper portion of rafting-channels the rafts may be made-up in the bed of the stream at any suitable place with shallow water. It has been already remarked that tanks are used to supply water to rafting-channels; they are preferable to any other mode of strengthening the head of water, as they permit rafting to be carried-on without interruption.

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* In 1883, a raft consisting of 11 sections, each containing 500 logs, and 800 feet long, was towed 600 miles from St. John in New Brunswick to New York in ten days by two powerful steam-tugs.

The constant struggle to extend and improve commerce by reducing the cost of transport is now chiefly directed in Germany to the work of improving moderate-sized rivers by canalisation. This cannot but have considerable influence on the rafting of timber and on the dimensions of the rafts and their mode of conveyance, &c., and arrangements should be made to allow sufficient way through bridges, locks and sluice-gates for the rafts. Accordingly, through the canalisation of the rivers Main, Neckar, Saale, &c., timber-rafting will be more and more extended to the lower courses of these rivers, if by forming suitable collecting-places out of the reach of floods and spacious tanks in which the rafts can be made-up and through which they can pass, the construction of large rafts is rendered possible. For if the rafting business is to be conducted on a large scale, spacious timber-tanks at central places to which rafts converge down the smaller streams are indispensable.*

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* ["*The Ouse Navigation.*—Goods are carried over a length of 72¾ miles, between Bedford and King's Lynn, and the Navigation possesses the power to stimulate trade very considerably.

"In the beginning of March, 1893, Mr. Thornber, who had been engaged by Mr. Simpson to carry out the restoration works, and who is now retained as manager of the undertaking, commenced work at the St. Ives staunch, and by September in the same year the navigation was reopened to St. Neot's. From October, 1893, to February 1894, the works were at a standstill for the winter, but in March, 1894, a fresh start was made, with the result that the first steam tug, bringing a number of barges with pig iron from the Tees for Messrs. Howard's works, and timber for Messrs. Hobson & Co., passed through the Bedford lock on the 25th July, and was duly reported in the *Journal* a month ago. Between St. Ives and Bedford there are 15 locks and 3 staunches, and there are also 42 flood-gates. The locks were all entirely restored and put into perfect working order. New sills, hollow quoins, and gate platforms were fitted at every lock, together with no less than 56 new lock-gates and 31 new flood-gates, all the remaining lock and flood-gates being put into thorough repair. Several of the locks were almost entirely rebuilt. Besides the repairs and rebuilding of the locks a vast amount of work was done in rebuilding and repairing bridges, horse pumps, landing stages, embanking, towing-path revivals, and last but not least not less than 50,000 tons of silt and deposit were dredged from the various shallows—to the vast benefit of not only the navigation but the tenants and owners of lands adjoining the river.

"It is hoped that the difficulties now in the way of the further development of the navigation will shortly be removed, and the prosperity of Bedford thereby further assured."—*Timber Trades Journal*, Sept. 7, 1895.

There can be no doubt that if similar attempts are made elsewhere in Britain to improve canal-traffic, that the British timber trade will greatly benefit, as heavy timber cannot be carried at a profit for long distances by rail.—Tr.]

2. *Rafts.*

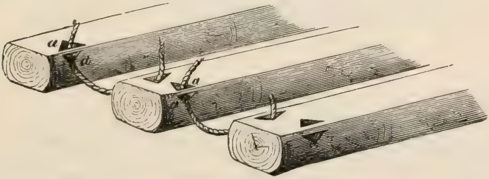
Raft-sections and rafts are made-up in various ways in different countries, the chief difference between them being due to differences in the kind of wood to be rafted. All wood-assortments may be rafted. At present, however, in Germany, Austria, Hungary, Russia, &c., only logs and sawn goods are rafted. Sawmill-butts are chiefly floated separately, and even rafting firewood across lakes has been abandoned in favour of the mode of floating with a chain of logs explained on p. 407. Wherever on large rivers the floating of firewood is not allowable, it is conveyed in barges, or as ballast on timber-rafts. Logs are bound together either by means of **withes** or **poles.**

(a) **Rafts of Logs.**

i. *Raft-Sections made up with Withes.*

A very convenient method of binding logs into sections is by means of withes. The logs are first stranded, being rolled along two pieces of wood gently inclined, into the water, and arranged as shown in fig. 241; the triangular holes are then cut as deeply as possible with a special hatchet. The corresponding holes (*a a*, *a a*) are then completely bored, and the logs pushed back into the water and tied firmly in raft-sections by strong withes.

Fig. 241.



These withes are generally spruce branches, or dominated spruce or hazel saplings, which have grown for a long time under the shade of larger trees; they are first baked in ovens and then twisted, their thick ends being held by a special contrivance.

The withes are from 1 to 6 centimeters (⅓—2 inches) thick, and their preparation and sale in many districts form a special trade. On the Vistula, ropes made of lime-bast are used for tying the logs.

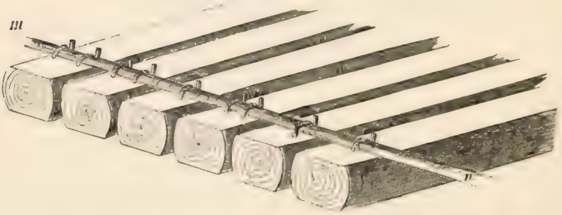
The number of logs which are bound-together into a raft-section depends on the breadth of the rafting-channel, and in certain cases on the width of the openings in the weirs. Usually the thicker ends of the logs are placed at one end of the section and their thinner ends at the other. In fastening the withes care must be taken to give the logs sufficient play, so that at any rate each log may be able to move slightly in a vertical direction. This is absolutely necessary for watercourses with numerous little rapids and with inequalities in the bed of their channel, as each section is then better able to accommodate itself to the uneven surface.

On channels with an even flow, and on the larger streams and rivers, the logs are fastened together as follows, with rigid raft-sections.

ii. *Raft-Sections fastened with Poles.*

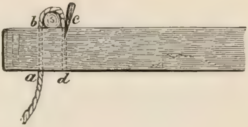
This second mode of making up raft-sections is shown in fig. 242; it is much more common than the former method, and is in use on nearly all steadily flowing rivers, the Spree, Saale, Oder, Elbe, Main, Rhine, &c. The logs are landed and bored through at (*a b*) and (*d c*) (fig. 243); they are then returned to the water and fastened to a pole (*m n*), as in fig. 242. Beech poles are generally used, but also spruce and silver-fir poles. The poles being placed over the ends of the logs which are to be

Fig. 242.



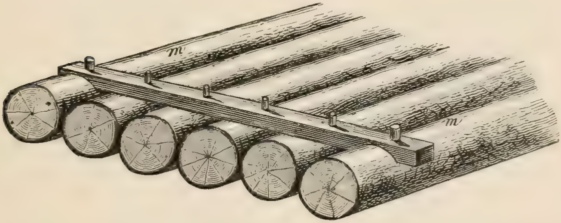
fastened and between the bore-holes in them, the thin end of a withe is passed through (*a b*) over the pole, and then into (*c*). The thick end of the withe gets jammed in (*a b*), and the thin end is fixed in (*c d*) by means of a wooden wedge. Instead of withes, the poles may be fastened to each log by iron nails or clamps. In this method the raft-section is a rigid body, and no independent motion is allowed to the individual logs.

Fig. 243.



This mode of fastening has the great advantage, that the logs are much less injured by the bore holes than by the larger holes made in the former case. In that case, the ends* of the logs must be sawn-off, whilst when the pole is used, the bore-hole can be eventually plugged with a piece of wood and the whole log become utilizable.

Fig. 244.



In powerful streams with numerous rapids, as in the river Isar, the poles are sometimes let into the logs. The latter are grooved at their ends, so as to admit the pole, and then fastened to it as before. The raft-section thus fastened is more rigid and stronger than without the groove. In Moravia, only the outer logs are grooved, and trenails are used to fix the pole to the logs (fig. 244).

The first condition for rafting is that the wood to be rafted is lighter than water, which is the case with all German woods except oak. Whilst, therefore, all other woods may be used alone to form a raft, oakwood must be mixed in rafts with other species which are light and will support it. For this purpose coniferous wood is always used, and is distributed among the oakwood in the raft-sections, so that they may be weighted as uniformly as possible.

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* These separate ends of floated logs are used in many places for pavin stables.

Poles are thus used, and are fastened to the logs with iron nails. In countries where the necessary coniferous wood is scarce, old wine-casks (on the river Moselle) are used to buoy up the rafts. It should also be noted that some oakwood will float well, and in that case rafts may be made-up entirely of light oakwood, as for instance, well seasoned Spessart oak.

(b) **Rafts of Sawn Timber.**—Of sawn timber, it is chiefly boards, planks and battens which are transported in rafts. [In India, rafts are made-up of logs, railway-sleepers and other scantling, and bamboos. — Tr.] Boards are fastened together in various ways in different countries, one of the commonest methods being as follows: — Ten to fifteen boards are fastened together on a bank of the stream, and 6 or 8* such bundles of boards so placed that the two outer bundles (*a a*) project beyond the others (fig. 245), and besides, the lowest board of each bundle projects about 40 centimeters (15 inches) beyond the other boards. This is done, so that in making-up a raft out of the sections the latter may dovetail into one another. The 6 or 8 bundles are now fastened together by

Fig. 245.

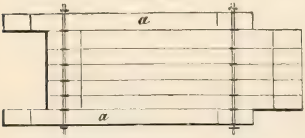
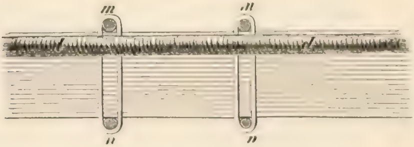


Fig. 246.



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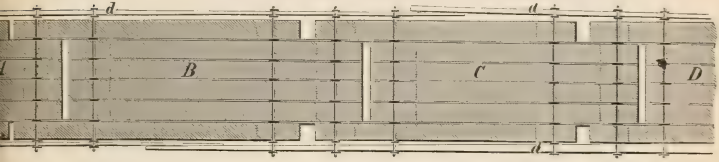
* These numbers are generally chosen, so that each raft-section may contain 100, 120, or 150 boards.

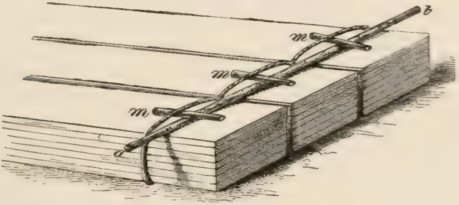
means of two or more pairs of poles, and one of each pair (*m m*) being placed above the bundles and one (*n n*) below, transversely to the raft-section, the withes are fastened round these poles.

Fig. 247.



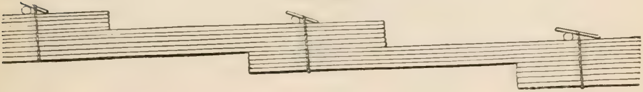
which thus enclose all the boards in the raft-section (fig. 246). Such a section is quite rigid. The raft-sections fastened

Fig. 248.



together on the land and slid into the water are then bound into rafts as shown in fig. 247. The sections A, B, C, & D,

Fig. 249.



are not dovetailed together by their projecting borders, but long slender spruce poles (figs. 246 and 247, *d d*) are fastened to their sides, passing from section to section, and thus affording rigidity to the whole raft.

Another mode of binding rafts is shown in fig. 248. The bundles of boards are tied with withes, but each withe passes through that of the neighbouring bundles, so that the bundles are slightly bound together. The raft-section (fig. 248) being thus made-up, a pole (*a b*) is fastened to it by the wedges (*m m m*). In the method of making-up rafts of boards, as shown in fig. 249, the bundles of boards are fastened one below the other, poles being used for the purpose, as in fig. 248. This method of rafting requires deeper water than the preceding ones.

(*c*) **Method of making-up Rafts.**—Several raft-sections are fastened together to make a raft. This is done either by attaching the ends of the sections together by withes, leaving them sufficient play—an important point in long rafts and in floating channels with sharp bends; or the sections are bound firmly together with withes, as is the practice on the river Kinzig, so as make a rigid raft. The spruce poles, as shown in fig. 246, are also used for fastening the sections together.

In binding the sections into rafts, the lightest ones are placed in front at the **head** of the raft, and the heavier ones behind in the **tail**. The more attention must be paid to this rule, the more rapid the stream of the rafting-channel, for the light sections float more freely than the heavy ones, and were the latter placed at the head of the raft, they would be pressed upon by the lighter ones, and the latter would even press the heavy ones down and mount on to them rendering the management of the raft impossible.

It is a rule that each section should be formed of stems equally long and thick; if the sections are small, containing 5 to 8 logs, the bases of the logs are all put together at one end of the section, and their tops at the other. Where the sections are larger, and the logs markedly uncylindrical, the butt-ends and tops of the logs are placed alternately side by side, in order to give the raft section a uniform breadth throughout. Such raft-sections are more easily united in a raft.

3. *Dimensions of Rafts.*

A distinction is made between rafts only one section broad, the sections being placed one behind the other, and large rafts formed both in breadth and length of many sections. The former class of rafts is in use in the upper and middle courses of rivers and brooks, whilst the latter are employed on large rivers and broad steadily flowing streams.

The former kind of rafts may, however, be very long, and often consist of from 40 to 70 sections hung one behind the other, containing altogether 300 to 500 logs and more. The large rafts, on the other hand, are often 50 meters (160 feet) broad and 200 to 250 meters (650—810 feet) long, and were formerly even larger.

4. *Mode of Rafting.*

A raft should be so conducted that it can be guided, its pace moderated, or it can be stopped at pleasure. On slowly flowing waters, ordinary **spreads** are used to guide the rafts. Where the current is rapid the rafts are made long so that they may travel slowly, and spreads are hung out behind the last section to drag along the bottom of the channel; the last section may also be opened out as in fig. 250, or a kind of **break** is used from the last section as shown in fig. 251 in section and fig. 252 in plan.

Fig. 250.

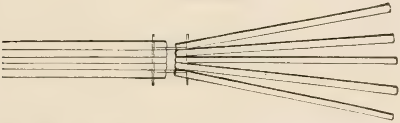
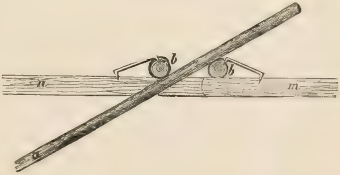


Fig. 251.

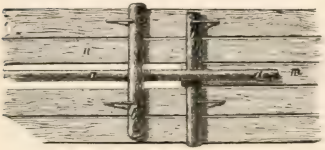


This break consists of a stout beam (*a*) passing between two poles (*b*) fastened to the raft by clamps, or withes. The break drags obliquely along the bottom of the channel, whilst it is firmly held above between the poles. In this way the pace of a raft may be regulated, and the raft directed through difficult passages and even stopped or stranded.

Long heavy rafts on fast streams with a steep fall have always several of these breaks on the last raft-section.

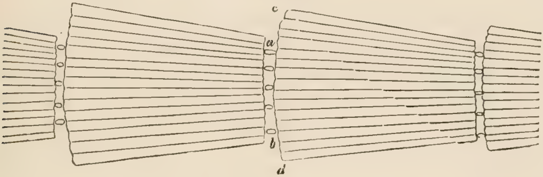
Rafting on shallow mountain-streams always demands the greatest attention and care, long experience of the rafting channel, and assiduous, trusty workmen. Men engaged in rafting require an amount of skill and daring which only experience from their youthful days can give. The workmen on the Wolf and Kinzig rivers and their tributaries, in the Black Forest, are veritable masters in the art of rafting, and it is now proposed to follow a raft down one of these rivers. The logs are floated down to a boom and sorted along the river-bank; they are then fastened together in its bed into raft-sections and rafts. The rafting-channel here is only 3 to 4 meters (10 to 13 feet) broad, with a rocky bed strewn with boulders and a fall of $\frac{1}{17}$ to $\frac{1}{12}$ (sometimes even $\frac{1}{5}$); in the worst places it is somewhat improved by simple weirs, and at the time the wood is floated has a depth of only 15 centimeters (6 inches). At longer or shorter intervals there are weirs in its upper course, and sluice-gates where its higher tributaries join it.

Fig. 252.



The raft, consisting of forty to fifty sections, is got ready, and is attached by ropes to the shore. The front section consists of only four small logs, which run together like a wedge in front, terminating in a short piece of planking. The second, third, and succeeding sections gradually increase in width, up to a middle width of 4 to 5 meters (13 to 16 feet), which is also attained by all the remaining sections of the raft, except the last, on which are the breaks, and which is only as broad as the water in the stream. The sections are fastened so that all the small ends of the logs are in front, which gives them a fan-shaped appearance as represented in fig. 253. Owing to this form, the raft may be actually broader than the stream and the passages through the weirs, provided that the latter are not narrower than *a b*, as the wings (*a c* and *b d*) of the sections then fold back over the rest of the section, recovering their former position as they emerge from the passage. It is therefore evident that rafts for floating on mountain-streams must be throughout quite loosely jointed. Suppose now, the long raft which is lying in the nearly dry bed of the stream and here and there overlaps it on both sides is to be floated; a few days beforehand all the sluice-gates of tributary streams must be closed, as well as the sluice-gates on the weirs down-stream, so that as much water as possible may be available in the upper course of the rafting-channel. Men are posted out on the hills along the stream to receive notices from those in charge of the raft and pass them on (in Galicia, telephones, of a total length of 50 kilometers in one instance, are used for this purpose).

FIG. 253.



While the raft remains firmly fastened by ropes to the banks of the stream, the filled reservoirs and weirs up-stream are opened, and the foaming flood rushes over and past the raft. This flood must be allowed half-an-hour's start, for the raft, once released, descends the stream quicker than the torrent, and the latter should be caught up, the raft would run into the dry bed of the channel, and its end-sections overshoot its front-sections, forming a chaotic heap of logs. As soon as a sufficient start has been given to the flooded water, the ropes are loosened, and most of the men mount the five or six front-sections to direct the raft. All the other sections, except the end ones, are left to themselves, and as the middle sections are often broader than the bed of the stream, the butt-ends of their wings dash along the banks. Men are placed also on the four to six last sections to manage the breaks. The breaks are now used at short intervals to slacken speed at narrow places and dangerous corners, and the men must know exactly when the front of the raft will reach a dangerous place, so that they may apply the breaks in time. When the breaks are applied, the whole raft creaks and shakes through all its members, and the last sections spring up and down according to the inequalities in the bed of the stream. The men with the breaks have hard work to do, for when the break is withdrawn by removing the withes which bind it to the raft, it has to be replaced in time for the next dangerous passage. Meanwhile, the raft floats so rapidly down-stream that a man running full speed along the bank can hardly keep up with it.

The first flooding of the stream may take the raft down from five to ten miles; then the water runs dry, and the raft lies on the bed of the stream until sufficient water is collected for a second flooding, when the work recommences. Once the raft has reached the broad and deep water below, there is no more difficulty about conducting it to the junction with a large river.

Only rudders are used in guiding rafts on large rivers. On the Rhine, different kinds of rudders are used; either spruce boards or long logs cut into shape of a board at one end. The larger kinds of rudders are so heavy that they are moved by a number of men, who push the rudders with their shoulders and take several strides in turning them. The men need not leave their places to move the smaller rudders. The rafts are pulled ashore by means of anchors fixed to the shore, and attached by ropes to the raft.

On the larger German rivers, both logs and sawn timber are rafted, and the rafts are further laden with firewood, oak planks and scantlings, laths, staves, vine-props, poles, and many other wares termed raft-ballast (*Oblast*).

[On the Brahmaputra and Ganges rivers, heavy logs of sal (*Shorea robusta*) and other wood which will not float in water are attached by ropes to long poles fastened across large buoyant boats, and are thus floated down-stream.—Tr.]

CHAPTER VI.

COMPARISON BETWEEN DIFFERENT MODES OF TRANSPORT.

The various modes of transport which have been described must, in different cases, differ considerably in value. For many forests no choice is possible; the local conditions absolutely decide the mode of transport. In the case of other forests, especially in moderately elevated or high mountainous regions, several methods may be followed, and the question is, which of them is preferable. Some of the chief points determining the choice of any particular mode of transport for a forest are as follows:—

1. *Conditions of the Locality.*

The configuration of the ground on which a forest is situated, the local climate, the density of population, the habits of the people and the method of agriculture followed, all influence the mode of wood-transport. In flat or hilly districts with mild winters, dense population and plenty of strong beasts of draught, it is evident that throughout the year there will be less difficulty in **transporting wood in carts or on forest-tramways**, than in mountainous districts; especially with steep slopes, where road-making is difficult on account of the destructive action of water, the number of beasts of draught is limited, and snow falls heavily every winter. Under the latter conditions, **sledging**, or a partial use of **slides** and **chutes**, are to be recommended. For descending very steep slopes, **wire-tramways** are best, and deserve more consideration than has hitherto been given to them.

Floating and **rafting** can be followed only where water-courses are available. As regards **floating**, mountain-districts are more suitable than hills and plains, where the presence of evenly-flowing streams renders **rafting** a suitable method; it is also permissible, and actually practised, along some of the weaker mountain-streams.

Although much thought has been expended on the advisability of abandoning **chutes** in mountainous countries, as they need constant repair and are known to be prejudicial to forests, they cannot as yet be dispensed with in high mountain districts. At the same time they may be gradually replaced by **sledge-roads** and improved **floating-channels.** **Log-slides** along made roadways will, however, always prove a useful method in mountainous districts, whilst in the Alps and other neighbouring countries **floating** has always been a prevalent mode of transport, and will remain so for many districts. Floating is much less followed in the plains and hills of North Germany, and even then chiefly for firewood, whilst **rafting** is extensively pursued in large rivers and canals. It is much easier to lay-out and use **forest-roads and tramways** in the plains than among mountains, but recent experience in the Vosges and elsewhere shows that the fact of a district being mountainous need not exclude these modes of transport, [which are gradually superseding floating.—Tr.]

2. *Wood-Assortments.*

Although every felling-area yields a number of different wood assortments, yet only a few form the great majority of its produce ; frequently one single assortment determines the revenue of a forest, and may therefore have a decisive influence on the choice of the mode of transport. Butts and firewood may be transported in various ways, but logs, poles and coppice-wood cannot be **floated,** though susceptible of all kinds of **land-transport,** whilst logs form the chief object of **rafting.**

In mountainous districts there are many forests which produce splendid long pieces of timber, but which at present only yield saw-mill butts, the stems being cut into lengths of 3 to 4 meters (10 to 13 feet) for floating, because, rightly or wrongly, the forest owners consider this mode of transport alone justifiable.

3. *Cost of Transport.*

The cheapest transport is also the best if it is sufficiently expeditious, and neither prejudices the forest nor the wood which it produces, in quantity or quality. The cost of transport is, however, greatly affected by the **cost of construction of the necessary works,** their **effectiveness and durability,** and the cost of their **maintenance.** It should be noted that the crucial point lies rather with the actual current charges for transport and maintenance of the works, than with the original capital expenditure on construction. From these considerations, however, it cannot be laid-down as a general rule, which method will be cheaper, or which dearer.

If only the cost of construction when compared with current charges were to decide the question in mountain-districts, a well designed net-work of cart-roads and slides must be abandoned for ever, for such works, especially among high mountains, require a very large capital expenditure ; all ideas of constructing forest-tramways would also then be illusory. Whilst, however, the original cost of other works, such as wooden slides or wooden works on a floating-channel, is comparatively low, the cost of maintenance in their case is very high. This is also the case as regards the cost of using wood instead of stone in works on roads or floating-channels. In most cases an estimate of the cost of the works will show, that unless the price of wood is very low, the greatest attention must be paid to **solid construction** and **durable material.** Even where **the prices of wood in the forest are locally and temporarily depreciated,** there can be no reason for neglecting modern and rational modes of transport, improvement in transport being always followed by higher prices.

How illogical it is that a forest owner should be frightened by the prospect of large initial expenditure on durable means of transport, is borne out by actual experience in the case of forest tramways. Independently of the great advantages they ensure for expediting the transport of forest produce to the centres of the timber-trade, for facilitating the sale of inferior assortments, for a rapid clearance of the felling-areas, preventing a loss of wood, &c., the transport charges are actually much lessened when compared with ordinary cart-traffic, so that good interest is obtained for the capital which has been thus invested. In the Grimmnig forest range near Potsdam, the cost of transporting a cubic meter (35·3 cubic feet) of Scotch pine timber on the 2½ kilometers (12½ furlongs) of forest tramway is 0·62 mark (7½*d.*), whilst its cost by cartage is 1·50 to 2 marks (1*s.* 6*d.* to 2*s.*). On the tramway in the forest range of Barr in the Vosges mountains, the cost of transport for a cubic meter of timber or firewood in the year 1889 was 75 pfennigs (9*d.*), whilst cartage for the same distance cost 1·84 marks (1*s.* 10*d.*). The forest tramway at Rothau in the Vosges may be confidently expected to yield 6 % on its initial cost, for the cost of transport per cubic meter is now 1·60 marks (1*s.* 7*d.*) compared with 4·50 to 5 marks (4*s.* 6*d.* to 5*s.*) by cartage. The cost of construction of the tramway in Ebersberg forest was very high, in round figures, 20,000 marks per kilometer (£1,600 a mile) for the main line, and 4,000 marks per kilometer (£320 a mile) for the branches (including lading apparatus, rolling-stock, &c.). It has, nevertheless, been possible to deliver a cubic meter of wood for 31 pfennigs (3½*d.*) at the nearest railway-station, for which the cost of cartage would be about 10*d.* The cost of constructing 105 kilometers of forest tramways in certain Prussian provinces averaged 4·32 marks per running meter (4*s.* a yard). The tramways in the Saxon forest ranges of Rossau, however, cost 8·95 marks per meter (8*s.* 3*d.* a yard).

Water-transport by **rafting and in barges, on streams and canals** has always been one of the cheapest modes of transport, and so, in many cases, has **floating**. As regards floating, however, the crucial points are: not too much cost in maintenance of works and conducting the business, and especially a considerable length of floating-channel. A regulated floating channel always involves expensive construction for reservoirs, dams, booms, maintenance of the banks of the stream, &c., and these consequently increase the cost of floating the more, the shorter is the floating-channel. For the annual conveyance to a distance of large volumes of butts and firewood, floating has always been one of the cheapest of methods practised, and often repays the cost of constructing works in solid masonry.

4. *Loss of Volume.*

The quantity of material loss of wood during transport depends on the **configuration of the ground, the mode of transport it necessitates,** and also on the **distance** over which it has to be transported. In plains and low mountain-ranges there can be no question of any loss of wood during **cartage** or **sledging** on good roads, or in transport on **tramways**; this is also generally true for **log-sliding.** There are also well-regulated floating-channels on which scarcely any loss of wood is experienced. In the higher mountain-ranges, however, where usually several modes of transport are combined, where there is an insufficiency of good roads, where the floating-channels are impeded by rocks and boulders, and where wood must pass over long slides, or be thrown down chutes, it is evident that loss of volume is unavoidable, in spite of every precaution. By the loss of bark (which for timber forms 10 to 15% of the whole volume) chiefly by friction during the process of landing, or of wood sticking on rocks, &c., or sinking in the stream—in such cases and where a long distance is floated over—the loss of volume may be considerable and reach 10–20%, or more.

[In India, a good deal of floating timber is stolen: between 1884 and 1886, 3,200 railway-sleepers were stolen from the Tons river, one side of which is not in British territory, out of 100,000 sleepers floated. There is also much scourage, owing to the rocky nature of river-beds, and railway-sleepers intended to measure 6′ × 8″ × 4½″ are cut 6¼′ × 8¼″ × 4¾″ to allow for this.—Tr.]

In order to give an idea of the loss of volume in high mountain-districts, the results recorded for the Ramsau forest range near Berchtesgaden will be given. Here, as in most mountain forest ranges, all modes of transport are used, and late in the spring the wood is thrown down chutes (p. 288); the consequent loss of volume, varying with the length of the fall and the nature of the ground, is not less than 2%, but not more than 12 to 15%, for were it greater than the last figure, the utilisation of such unfavourably situated forest must be abandoned. Once the wood has thus gone a certain distance it is conveyed further by means of slides, roads, or floating-channels. In sliding, if the slides are not interrupted by chutes, there is little loss, scarcely more than 1% on fairly good slides, but if the slides are very steep and combined with chutes, the loss may attain 15, 20 % and more. In transport on sledges and carts there is loss only when part of the wood is dragged behind the sledge as a break, and even then, the loss seldom exceeds ½ %. Where sawmill butts are slid on the ground, or thrown down-hill, as is sometimes unavoidable, greater friction and loss ensues, which is at least 10 %. The loss in floating varies between 2 and 15 % of the volume launched. Since highly different modes of transport are often combined, as in the Ramsau forest range, it is difficult to assign the amount of loss to any one of them in particular, but on the whole it may be fairly admitted that in land- and water-transport there is 6 % of loss, of which 4 % on land-transport, and 2 % by water. According to old observations made at the salt springs of Berchtesgaden, the loss in land-transport and floating to the timber-depot there, was 5 % from the Bischofswies, 8 % from the Hintersee, Ramsau and Schwappach, 20 % from the Königsee, and 30 % from the Röth, a fall over a steep incline 600 meters (1,950 feet) high. At present, in all these districts, great improvement has been effected by constructing good sledge-roads in all directions.

5. *Deterioration in Quality of the Wood.*

The deterioration in the quality of wood during transport consists in **external and internal damage.**

The former kind of damage may be recognized as soon as the wood has reached its destination by a brush-like loosening of its fibres at either end, in the case of both butts and firewood billets. To this may be often added a certain number of radial cracks.

The internal damage is of much greater importance, affecting as it does the soundness of the wood; land-transport cannot have any influence in this respect, but floating is held to be a cause of decay, which in the case of sawmill butts is often considerable. Provided the floating were properly effected, it could not alone be responsible for this, supposing that it were always possible to take the necessary precautions. But frequently this cannot be ensured, and consequently in the outturn of the sawmills there must be a certain proportion of unsound boards and scantling. In so far, therefore, as floating actually increases the difficulties and practical impediments in the way of a rational treatment of wood, it is advisable, wherever it is not susceptible of improvement, to limit its use, at least as regards valuable timber.

6. *Influence of Railways on the Timber-Trade.*

It is easy, from observation of the freight of goods-trains which pass through forests, to form an idea of the share that the ordinary railroads of a country take in the transport of wood. By the co-operation of branch-lines and road-railways the meshes of the railway-net are constantly narrowing, and a great and important future is being prepared for facilitating the transport of wood by the use of railways, and by uniting them with main forest railways and portable tramways. Plains and hilly districts alone can fully profit by these benefits; and although mountain forests, as we have seen, may also participate to some extent, it is chiefly long gently inclined valleys, penetrating the interior of mountain-districts, where projects for the construction of forest railways can at present be entertained. In general, however, the decisive arguments for and against the adoption of a forest railway are:—whether large quantities of wood are available for trade along a given line of export, or the produce of a forest has to be distributed in detail to satisfy merely local demands; the total amount of the produce in question, which may be temporarily augmented owing to damage by storms, insects, or other causes of injury; and sometimes the probable duration of the demand for the produce. This last motive may also involve serious danger to the forest, in case the existence of a forest railway should lead the manager to overstep the limits of true forest conservancy by overfelling.

It is in the interests of sylviculture, especially for the reproduction of the standing-crop, to extend portable tramways as much as possible, in order to remove the produce of secondary fellings and standards in full-sized logs without injury to the young crop, and thus supply a quick and cheap transport of wood from the constantly shifting felling-areas to the nearest timber-depot, or to a junction with an ordinary railway-line. It is, however, evident that for such a purpose only plateaux and plains can be utilized. The introduction of portable tramways into the forest range of Einsiedel-Bebenhausen is well worthy of imitation, and here also a considerable saving of expense as compared with cart-traffic has resulted.

7. *Canals.*

In lowlands, canals are even more useful than railways, owing to the reduced cost of transport which they involve. The network of canals in Prussia is now being rapidly extended, and enormous quantities of indigenous and foreign timber are carried by the various canals. Canals are now being constructed to unite the Rhine with the Weser, and also with the Danube and Main. [The acquisition of English canals by railway companies is against cheap inland traffic.—Tr.]

8. *Conclusion.*

Facilitating wood-transport by increasing and improving the means of communication within and outside the forest has become a question of the first importance. Forestry has in many places lagged behind almost every other industry in this respect. Owing to the situation of forests, transport from them is most difficult, but this does not relieve foresters from the duty of making every endeavour to utilize all present engineering resources, so as to reduce, as far as possible, the present high rates of timber-transport. Apparently the present tendency is to curtail floating in favour of land-transport, either by cart-roads or tramways.

Success in carrying out this programme will at any rate be justified by the consequent improvement in the quality of timber; its adoption is further enforced owing to the constantly increasing utilization of water-power by other industries, in most cases incompatible with the use of the same streams for floating. Changes in the mode of transport are constantly occurring, as sawmills are established more and more in the interior of forests. Nevertheless the time is far distant when floating and rafting will completely disappear from the list of means of forest transport, and in many districts they can never be dispensed with.

CHAPTER VII.

WOOD-DEPOTS.

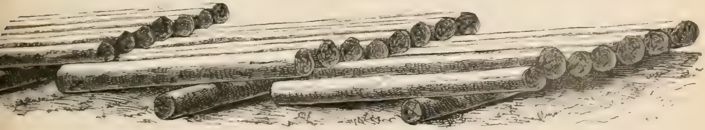
In order to collect transported wood in an orderly way, and store it for a longer or shorter period, a site must be selected for a permanent wood-depot, from which it may pass into the hands of the wood-merchant or consumer. Cases not unfrequently occur, when it is necessary to keep the transported wood, especially logs and sawmill butts, in water until it is used, but usually wood is stored on land and kept dry.

The arrangement of a wood-depot differs according as the wood has been transported by land or water.

1. *Land-depots.*

Any well-drained area sufficiently extensive and accessible to cart-traffic will serve as a depot for wood transported on carts, tramcars or sledges. In collecting and storing logs, which are to be transported further by the purchaser, all that is required is to arrange them in an orderly manner, after duly considering the available space. If there is plenty of room, and the logs are to be numbered, measured and registered at the depot, they may be arranged as shown in fig. 254, or the logs and butts may be placed in three or four layers, crosswise, one above the other. If there is not much room, and no necessity for estimating the volume

Fig. 254.



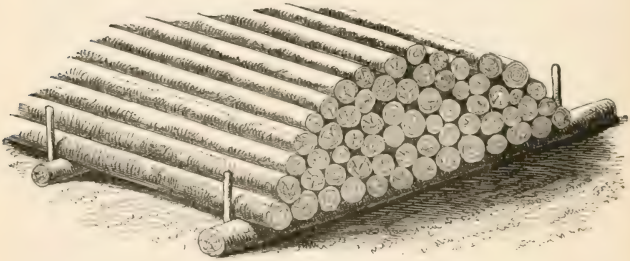
of the wood, the logs and butts may be rolled into heaps, as in fig. 255.

In any case, precautions must be taken to keep the logs raised above the ground, and to secure for them free admission of the air.

In case the wood is sold by lots at the depot, it should now be arranged in suitable lots, according to trade custom.

Wherever logs are to be stored for a number of years, it is best to keep them **under water**, provided that they are completely immersed, and there is a moderate inlet and outlet of the water to prevent its becoming stagnant. Logs are then most securely preserved for several years from decay and from cracking, and can be readily converted into planks, scantling, &c. If it is not possible to submerge the wood, and large quantities of wood must be stored dry for several years (as after insect-attacks, storms, &c.), the greatest care must be taken to isolate them from ground moisture. Logs are, therefore, thoroughly barked and rolled into parallel rows one above the other, in shady places which are not exposed to dry winds ; the stacks of logs are also lightly covered with sods, to protect the logs from cracking in dry weather. The wood suffers least of all on northern aspects. Under similar circumstances, spruce logs keep better than silver-fir or Scotch pine, and logs better than butts.

FIG. 255.



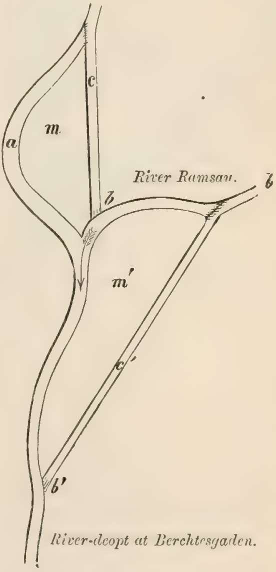
In depots used for **firewood** brought by land, only the best class of firewood will repay further land-transport. Firewood requires the same precautions as timber, and firewood depots should also generally be fenced and furnished with a gate which can be locked. The arrangement of the wood is done in a similar way to that in river-depots, which will be now described.

2. *River-depots.*

A large number of depots are used for storing wood after transport by water, and different arrangements are then required from those described under land transport, especially after the wood has been floated.

The necessary characteristics of a good river-depot are:—immediate proximity to the floating-channel; a site thoroughly exposed to air and wind; the soil formed of sand, gravel or boulders to a depth of at least half a meter (1½ feet)—otherwise it should be paved with large stones; elevation of a few yards above the highest flood-level of the stream, or in case the depot is so arranged that the wood lands itself, a sufficient fall in the different basins of the depot, which are separated by sluice-gates. In many cases it is also necessary to include protective works against floods, which will be described further on.

FIG. 256.

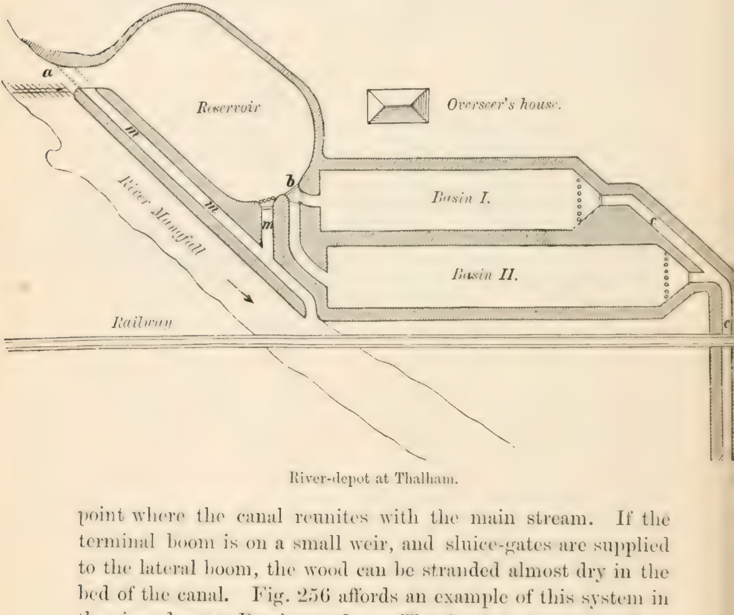


River-deopt at Berchtesgaden.

Wherever only a little wood is floated and labour is plentiful, a bank of the stream above the boom, if otherwise suitable, is generally selected on which the wood is landed. As all the wood must then be dragged from the stream, and many men thus simultaneously employed, the depot should extend for some distance along the river-bank, and its breadth be reduced to a minimum, allowing sufficient room for storing and removing the timber.

It is a good plan to dig a canal from the floating-channel, which reunites with it lower down stream. The land between the two watercourses will then form a good depot. At the point where the canal leaves the floating-channel, the latter is barred by a lateral boom, the terminal boom being placed at the point where the canal reunites with the main stream. If the terminal boom is on a small weir, and sluice-gates are supplied to the lateral boom, the wood can be stranded almost dry in the bed of the canal. Fig. 256 affords an example of this system in the river depot at Berchtesgaden. The floating-channel (*a*) from the Königsee here joins the river Ramsau (*b*); canals and depots are provided for the wood from the Königsee at (*c*) and (*m*), and at (*c′*) and (*m′*) for the wood from the Ramsau, whilst the terminal booms are at (*b*) and (*b′*). The canals are paved with stone, and the wood is stranded almost dry.

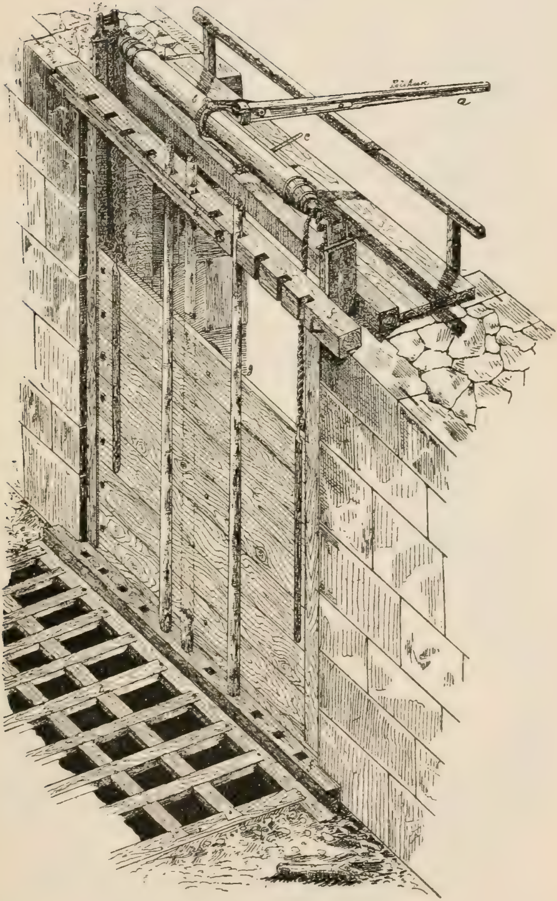
FIG. 257.



River-depot at Thalham.

Side-canals often bifurcate from floating-channels and lead to all

FIG. 258.



Sand-grating and sluice.*

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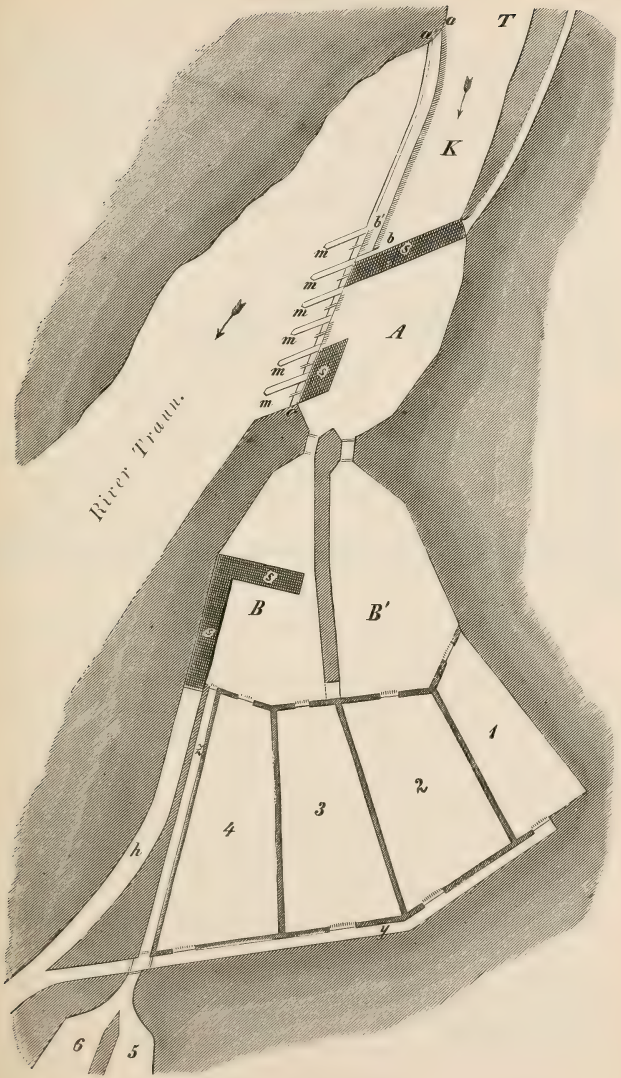
* From *Atlas zum forstliche Transportwesen,* Förster, Vienna, 1888.

parts of the depot, they again unite into main canals, and these rejoin the main floating-channel. In such cases, the floating wood and water are distributed, and the pressure on the sluice-gates and gratings, with which each side-canal is provided at its inlet and outlet, is as slight as may be. In order to attain what is desirable in this respect, and avoid fracture of the booms and other calamities from floods, the main canals, and sometimes the floating stream itself, are provided with outlets. The best and largest river-depots, such as those which supply wood for salt-mines in the Alps, are constituted on the principle of leading the floating wood out of the main stream and distributing it as much as possible in the different basins of the depot, so as to reduce pressure on the booms and save manual labour in landing the wood. As an example, the newly-constructed river-depot at Thalham, near Munich, may be cited (fig. 257). Firewood is floated down the river Mangfall to the boom (*a*), and hence by a side-cut into the reservoir, where the wood is collected in a preliminary manner. The reservoir has two outlets (*m*, *m*) as a protection against floods; at *b* are two canals, each provided with booms and sluice-gates, leading to the basins (*I* and *II*), where the wood is received. The basins are entirely surrounded by solid earth-dams faced with masonry, paved with stones, and provided at their entrances and outlets with sluice-gates. At the end of the basins are gratings, through which, after opening the sluice-gates, the superfluous water can pass through the outlets (*c*, *c*) back into the river Mangfall, leaving the wood behind the grating. By this arrangement the current and the floating wood can be conducted into either basin until it is full of wood. In a few hours, owing to the sloping nature of the bottom of the basins, all the water can be withdrawn through *c*, and the wood left stranded. It can then be split on the spot, and removed in a perfectly dry state. The firewood thus stored in either basin can be conveyed to Munich, as required, by the adjoining railway.

Fig. 259 represents the arrangement of the river-depot at Traunstein; it is constituted on the same general plan as that at Thalham, but is distinguished from it by the more elaborate protection afforded against floods and silt. The floating-channel (*K*, *a*, *b*) is cut off from the river Traun by a lateral boom (*a*, *b*)

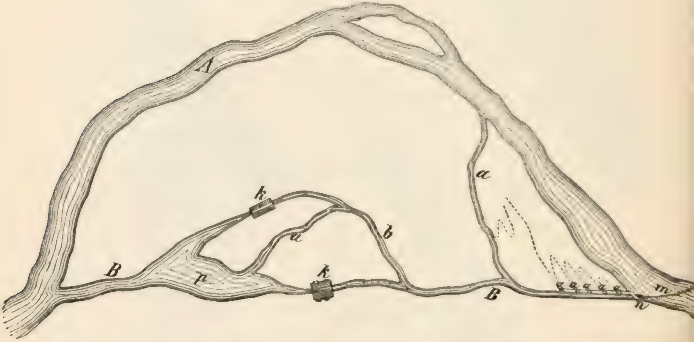
FIG. 259.


a
T
a
K
b'
b
S
m
m
m
m
m
m
m
c
A
S
River Traun.
S
B
B'
S
1
2
3
4
z
h
y
6
5

Wood-depot at Traunstein.

and a stone overflow weir (*a′*, *b′*). This channel is widened-out into the reservoir *A*, and *m*, *m*, &c. are outlets between solid hewn stone masonry walls, which can be closed by means of gratings and sluice-gates. The flow of water through these outlets may be increased by means of culverts (*s*, *s*), which are covered with gratings (fig. 258). From *A*, the floating wood passes into the preliminary collecting basins *B* and *B′*, and, in case of necessity, water can be removed from them by means of the culvert (*s*) and the canal (*h*). *B* and *B′* serve to distribute the wood into the basins 1, 2, 3 and 4, whilst the more remote basins 5 and 6 are supplied from *B* by the canal (*z*). The outlet (*y*) leads the water back into the river Traun.

Fig. 260.



In all mountain-streams where floods occur, sawmills, as well as wood-depots, are placed in side-channels. This is essential, so that each mill may obtain its water-power separately and leave the main stream free for other mills and for floating purposes. In fig. 260, the stream *A* is closed by a long lateral boom (*m*) at the outlet of the mill-stream *B*. At (*n*) is a second boom with a removeable grating, behind which are sluice-gates, so that both the water and the floating wood may be under control; (*a*, *a*, *a* . . .) are outlets. The sawmills (*k*, *k*) receive the butts directly by water, and the sawn boards are bound into rafts below the mills and rafted down-stream.

(b) **Method of Landing and storing Floated Wood.**—As soon as the wood has been collected in front of a boom, the measures taken for landing it must be so arranged that it may be brought out of the water as soon as possible. Whenever the depots are arranged so that the wood becomes stranded of itself (pp. 434–436), the workmen must be stationed at the various sluice-gates and gratings, and be carefully instructed in the manner of landing the wood.

Wherever the wood has to be dragged up to the depot, different methods of doing so are followed for sawmill butts and firewood. Butts are either rolled up the river-bank, or dragged up an ascending slope by horses or by machinery worked by the driving-wheel of a sawmill. Firewood billets are either spiked by a floating pole and thrown upon the river-bank, or passed from hand to hand by a chain of workmen. In some places machines are used for landing firewood.

These machines consist of two horizontal rollers, one of which is alongside the water, and the other up on the bank of the stream. Two chains bound together link by link, and provided at short intervals with projecting iron hooks, are passed round the rollers ; the billets of wood are then placed on these hooks, whilst the chains are set in motion by the upper roller, and the hooks ascend the river-bank with the billets, which fall off as they reach the upper roller.* These machines are specially useful when the depot is situated on a high, steep, sloping river-bank.

3. *Methods of Storing Wood.*

The landed billets are conveyed to the stacking-yard in low tramcars or wheelbarrows, the round pieces being previously split; they are then stacked, beginning at a point in the depot the furthest removed from the water. In stacking, great care must be taken not to occupy too much space, to leave sufficient room for ventilation between the different stacks and erect the latter in a stable manner. With this object, the stacks of firewood are placed in long rows, in the direction of the prevailing wind, and made as high as their stability will permit. This is rarely higher than fifteen to eighteen feet. In erecting a stack, the base is first prepared as in fig. 261, in order to keep the wood as much as possible from the ground, and prevent its deterioration; or merely two parallel lines of billets are laid on the ground, on which the wood is stacked. In the damper parts of wood-depots, especially in the case of large depots where there is not enough fall to allow the water to drain-off rapidly from the wood, and wherever the wood is stacked whilst still wet, this should be done as in fig. 262.

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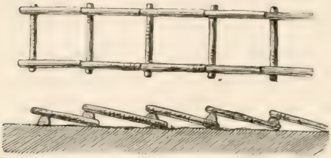
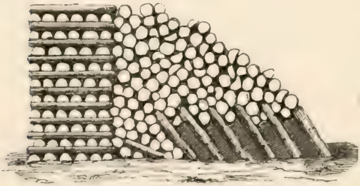
* On the river Ilz near Passau, there are 10 of these machines which save 40% of the former cost of manual labour for landing the firewood. 180 to 200 stacked cubic meters (100 to 140 loads) of wood can thus be raised in a day. At Hals, also on the Ilz, similar machines worked by steam-power are used for raising butts up to the depot, 8 meters (26 feet) high. The heaviest kind of butts are thus raised.

Fig. 261.



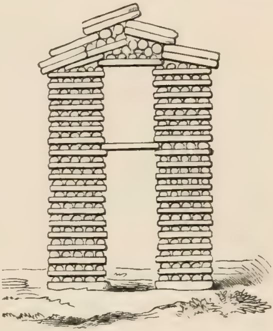
Each stack must be finished off at both ends by crossing the billets to prevent it from falling. In very long stacks, it is advisable to place some rows of crossed billets in their centre, so as to give more stability to the structure. In the case of very high stacks, the crossed billets at their ends should be connected by transverse pieces, as in fig. 263. Between any two stacks there should be left a space of at least two feet, to allow for ventilation. Wherever, on account of scarcity of space, it is necessary to reduce the distance between the stacks to two feet, and the stacks are also high, two adjoining stacks are joined, as shown in fig. 263, which greatly adds to their stability. Wherever carts must pass between the stacks to remove the wood, a sufficient passage must be allowed between adjacent stacks for their passage. Not unfrequently, however, owing to want of space, four to six stacks are crowded together without any intervening space, as, for instance, at Prague, where the arrangement shown in fig. 264 is followed.

Fig. 262.



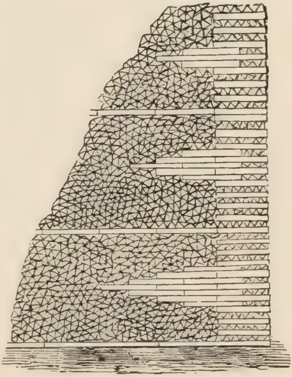
Where large quantities of firewood remain stored for a long time at a depot, a roofing of billets is often supplied, as in fig. 263. This excellent mode of stacking keeps the wood dry without any considerable cost. Wherever, in high stacking, the stack has become higher than a man's chest, stands must be used from which the billets may be handed to the stacker. This is especially the case with roofing. The billets should evidently be piled as densely as possible, and the walls of the stacks made vertical.

FIG. 263.



Many wood-depots in towns are intended to facilitate the sale of wood to small purchasers. In such cases the wood must be supplied in ordinary sale-lots. The stacks are then usually twice as high as the billets are long, and are separated by upright posts. In other depots the wood is separately measured for each purchaser. Whenever the sale of firewood is carried on in detail, it should also be sorted according to quality; this assortment of the wood is effected as soon as the wood is landed, the various pieces being brought together from all parts of the depot. When once the wood has been sorted and stacked, the stacks are numbered and measured.

FIG. 264.



Wherever firewood is piled in mixed stacks without separation into sale-lots, the measuring is done simply by taking the length and height of each stack; where the billets are crossed, a deduction must be made from the volume, the amount of this deduction being ascertained by experiment and averaging the seventh or eighth part of the length of each stack. Wherever the firewood is arranged in sale-lots, its measurement simply consists in counting the latter.

4. *Registration of the Receipts of Wood at a Depot.*

It is quite obvious that in all wood-depots an account must be kept of all the receipts of wood both as regards volume and quality. The volume of the timber and of the stacks of firewood is ascertained in the usual manner. A further allowance has, however, to be made for the loss incurred during the transport of the material, which also naturally involves measurement of the wood before it was transported. Wherever wood has been carefully transported by land, the loss is either inconsiderable or absolutely nil, but when wood has been dragged over rough ground, or thrown downhill, &c., there may be a considerable loss of volume during transport. Loss during transport by water may also vary between 0 and 10 or 12°/₀. It is also obvious that the volume of the sunken wood which has been recovered should be deducted from the loss during floating, and that any losses occasioned by careless land-transport previous to floating must be excluded from loss due to floating alone.

The following circumstances influence the loss of floating wood:—the condition of the works on a floating-channel; its length; the kind of wood floated and its comparative dryness; the manner in which the wood is stacked in the forest, and in the depot; the question whether wood has been brought down to the launching place on slides or roads; also extraordinary occurrences such as floods, theft, &c.

CHAPTER VIII.

DISPOSAL AND SALE OF WOOD.

The disposal and sale of wood includes all the transactions by which wood passes directly or indirectly into the hands of the consumer. A distinction is made between the **disposal of the wood**, and its **sale**, as two questions are pending: to whom in the first place should the wood be delivered, and then, how shall this be effected ?

Section I.—Disposal of Wood.

According to the nature of the produce of a forest, the demands made on it, and the various intentions of its owner, different destinations may be given to the converted wood on a felling-area. The demands on the forest are of a double nature : they are either legal demands which limit the freedom of the owner in disposing of his produce, as in the case of forest servitudes, contracts, &c.; or the owner is absolutely free to dispose of the produce according to his own wishes. In the latter case the question arises, whether the forest owner will be disposed to consider the requirements of residents in or near the forest; or will merely study his own direct interests, a very different matter. It is obvious that in both of these cases he will first of all consider what wood he requires for his own special wants.

As all these different modes of disposal of forest produce remain about constant year by year for a separate unit of forest management, there is generally no difficulty in subdividing the annual yield of a forest according to certain **fixed heads**, which must now be considered *seriatim.*

1. *Wood delivered to Right-holders.*

Wherever a forest is burdened with wood-servitudes, the right-holders have the first claim to the produce of a felling-area.

The legality of all claims for wood, as a right, must first be proved by reference to the map or record-book of the forest rights; and this enquiry is often a serious business when the right-holders' wood has to be distributed in small lots among a number of persons. In such cases, in many districts, fixed days are assigned for the right-holders to attend the forest manager and make a declaration of their demands. This declaration must be examined, rectified, and if needful referred for confirmation to the superior officials. Every delivery of wood to right-holders must be made on presentation of a written order from the forest manager, and a receipt for the wood must be given by the right-holder.

If the right is to firewood, the quantity and quality of the wood being stated, the forest owner is least seriously affected by the right; and in the next degree, when the right is to the kind of timber prevalent in the forest. If, however, the right is to all wood of a certain class, for instance, all branches and round billets, all the brushwood or stump-wood of a felling-area—if also the quantity depends on the manner in which the wood is converted and sorted—the distribution and supervision of the right-holders' wood becomes more arduous, and often involves complaints of short measure from the right-holders. Great care must then be taken during the conversion and sorting of the produce; wherever also the dimensions of the right-holders' wood are precisely given in the statement of rights, this must be carefully attended to during the conversion. The most hurtful rights are those which are not fixed in quantity, but only by the requirements of the right-holders. If such rights to firewood should burden a forest, and no legal definition can be obtained of their extent, an annual computation must be made of the volume required by each right-holder, or for each class of household. This burdens the manager with a tedious undertaking, beset with all kinds of difficulties.

Deliveries of building timber to right-holders are of a similar nature. Such a right can only be limited to the actual requirements of the right-holder, according to the number and dimensions of the buildings in question. It is the duty of the forest officials carefully to ascertain the actual requirements of material for repairs or new buildings, whenever a demand for building timber is presented. If the demands of the right-holders are supported by estimates made by trustworthy builders, the forest manager is spared much trouble. Deliveries of wood for implements or industrial purposes are also similarly arranged.

2. *Wood delivered to Contractors.*

Frequently a forest owner is under agreements, more or less binding, to supply wood to neighbouring industrial works; such as iron-foundries; smelting-furnaces; sawmills; factories for furniture, pyroligneous acid, wood-pulp, &c.; or to contractors or wood-merchants. Wherever the manager is bound to deliver a certain volume of wood to any such establishments, their claims must be satisfied after those of the right-holders. As a rule, except after some extraordinary calamity such as a storm, snowbreak, &c., the manager is not bound to deliver any fixed quantity of wood to a contractor; but an agreement is made, to deliver to a factory or a wood-merchant all the material over after satisfying the local demand, or all the wood of a certain class, such as round billets, &c. Whether or not a forest owner should undertake such contracts, especially in the case of timber, depends chiefly on the market there is for his wood. In extensive forests which are not properly opened-out by roads or other means of communication, managers of industries which utilise wood and wholesale wood-merchants are often the only purchasers; the forest owner is then willing to submit to an otherwise burdensome agreement, in order to increase the forest revenue. Wherever there is a good competition for the wood, there can be no reason for contracting beforehand for its disposal. Not unfrequently, however, the possibility of a good sale of timber, even in the forest itself, depends on the maintenance of such industries, especially sawmills, which consequently do not reduce the prices of wood. This is due to the fact that sawmills favour the transportability of wood and convert it into actual merchandize. Even in this latter case it is advantageous to the forest owner, who wishes to support such industries in his forest, to bind himself only partially. Thus it is advisable to make contracts only for 2 or 3 years, and especially when trade is slack. Finally, in deciding the terms of a contract, great care and foresight must be shown by the forest owner, or his interests will be seriously prejudiced, as long experience has fully proved. Wherever it is possible, the owner should not guarantee the quality and volume of the material to be delivered ; and if certain assortments are to be supplied, they should be only such as are usually prepared in his forest, otherwise it is better to abstain altogether from a contract.

3. *Satisfaction of the Requirements of the Forest Owner.*

Every forest owner, whether on a large scale or not, requires wood for his own use, and will therefore, after satisfying the demands of right-holders and contractors, consider what are his own requirements.

A private owner of forests requires firewood, building material and wood for gate-posts, fences, &c. If he owns any works, the wood necessary for them should also be supplied.

Municipalities and Communes owning forests require firewood for public offices, schools, &c. ; they also grant firewood free of charge to school-instructors and ministers of religion ; timber for repairing churches, public buildings, &c. ; every household has finally to be supplied with firewood and building material according to its requirements.

The **State,** as owner of forests may be expected to supply firewood and timber to meet the requirements of the Forest Department, of its mines and smelting furnaces, of the Public Works Department and other public bodies.

(a) **The requirements of the Forest Department.**—Wood is required for forest departmental purposes, for fencing nurseries, parks, and lands occupied by forest officials, but especially for the contsruction and repairs of departmental buildings, woodcutters' huts, roads, bridges, slides, &c.*

(b) **Wood required for Mines, Smelting Furnaces, &c.**—Where works of this nature are very extensive, and require annually the yield of entire forests for their maintenance, it was formerly customary to assign the management of a sufficient area of forests to the administration of the works, in order that the forests might be managed purely in their interests (such forests are termed in German, *Saalforst*, *Montanforst* or *Reservatforst*). Experience has, however, shown that such an allotment of entire forests to mines, &c. has not resulted in any benefit to the forests, on the contrary, in some cases, they have been thus destroyed. Forests have therefore, recently, as in Bavaria, been withdrawn from the administration of the mines, and the necessary wood is now furnished to them by the Forest Department.*

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* [All wood used in this manner should be clearly shown in the registers of forest produce.—Tr.]

(c) **Wood required by the Department of Public Works.**—The requirements of the Public Works Department for rectifying river-banks, for railways and less frequently for public buildings, gave rise to similar assignments of forests (such as coppice for growing fascines) to that department, with this object in view. Experience has shown that it is disadvantageous to the State to deliver timber for building purposes to the public works officials from the State forests, the procedure being uneconomical and inimical to the State budget. Even forest buildings do not form an exception to this rule.

[As the French Navy has still the right of preemption of wood, chiefly oak, in the French State forests, a short account of the procedure in such cases will be useful. Royal ordinances dating from A.D. 1318 allowed the French Navy the right of preemption of wood in all the forests of France, whether private or otherwise, and agents were sent by the naval authorities to mark trees in the felling-areas. This right continued up to 1838, when it was abandoned (with, however, the power of resuming it if necessary) in favour of purchasing the required wood in the open market. After the latter procedure had been in force for 20 years, the right of marking suitable trees in the State forests was resumed by the Navy in 1858. In 1866, rules regarding wood for the Navy were framed by the Forest and Marine Departments, and may be summarised as follows :—

Before the trees are marked for felling in any State forest, the agents of the Navy mark with a circle of oil paint any trees in compartments where fellings are in progress, which they may consider suitable for naval construction. These trees are then marked for felling at the usual time, and in the same way as the other trees in the felling-areas, but with special marks. All the marked trees are sold standing, as is usual in France, but the purchaser pays only for the crowns of trees chosen for the Navy, excluding any boughs which have been specially reserved. He then fells all the trees, and a naval engineer examines those stems which had been specially marked for the Navy, and then proceeds to convert them into the necessary pieces and remove them to a sea-port. The price is fixed for a period of five years at so much a cubic meter, and a current account kept between the Navy and Forest Department. Boppe, *op. cit.*, p. 228.—Tr.]

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* [A similar case is the Kumaon Iron Mining Company's Forest Grant, in the N. W. Provinces of India, which has now been resumed by the State.—Tr.]

(d) **Wood required for Floating-Channels and Wood-Depots.**—It was formerly considered the duty of the State to maintain large firewood-depots in districts where there were no forests, and to convey the wood there at its own charge. In order to carry-out this object a special floating department was organised, to which the necessary volume of wood was delivered from the German State forests. Since means of communication have been extended and with them the trade in firewood, the necessity for the department has disappeared, and it has been abolished.

(e) **Wood required for Sawmills.**—There are several German States and Communes owning sawmills, the management of which is more or less independent of the Forest Department. (For instance, Brunswick, Alsace and Lorraine, Hannover, Baden, &c.)

(f) **Wood given to Privileged Persons** (*Deputathölzer*).—Under this heading comes wood given as part of the salary of Government servants; in some States, as in Mecklenburg, inferior firewood is also given gratis to the poor.

Special orders are given by superior authority to the local forest officials as regards the delivery of wood of the different classes referred to above.

4. *Disposal of Wood by Sale.*

All wood which is not required under any of the above headings will be sold. The next section describes the different modes of sale, the only point of interest here is into what hands the wood should come after being sold. A distinction is thus made between satisfying **local demands** and **sale of wood to traders.**

(a) **Satisfaction of Local Demands.**—Care for the protection and tending of his forest will often lead a forest owner to consider, first of all, the requirements of people living in or near the forest. As this can be done only to the extent of their own absolutely necessary requirements, it will suffice, if, as a rule, the less valuable assortments are set-aside for this purpose; usually only inferior assortments of firewood and building timber are thus sold in a market limited by the exclusion of wood-merchants.

Whether or not the State will undertake to satisfy local demands on a large scale depends on its vacillating interpretation of the laws of national economy.

(b) **Sale of Wood to Traders.**—The sale of wood to meet local demands is opposed to its sale to traders, as then an open market is understood. When once a forest owner has satisfied local demands, his desire to sell the rest of his produce at the highest price attainable is distinctly to the advantage of his forest. It is chiefly the best timber and wood which can be exported with profit to a distance with which the forest owner can speculate. For very many forests the mode of treatment and conversion depends on the timber-trade, and many forests can be worked only with the help of the wood-merchant, local demands being small and easily satisfied. Disposal of wood for trade purposes is therefore in most forests the most important mode of utilising them.

5. *Loss of Wood.*

Cases occur where wood already registered as received may be lost, for instance by fire, theft, &c. The possible loss of wood is therefore a mode of its disposal.

SECTION II.—SALE OF WOOD.

Wood, like every other raw material, is an object of trade, and is sold in various ways, the *pro* and *contra* of which will be here described. As, moreover, every forest owner desires to obtain the highest possible revenue from his forest, and this is chiefly determined by the price he obtains for his wood, the question arises as to the general trade-principles governing the sale of wood in order that this object may be attained. The modes of selling wood may be distinguished in two ways: first, **the form in which the wood is offered for sale** by the forest owner, and secondly, the **different kinds of sale**, depending on the manner in which the price is determined.

1. *Form in which Wood is Sold.*

Wood may be sold either **by detail** after conversion into logs, stacked firewood, &c., or by **standing trees.**

(a) **Sale by detail.**

Sale by detail follows after the felling, conversion and removal of the wood to a forest-depot, which operations have been effected by a body of woodcutters engaged for the work by the forest owner. The wood is sold in larger or smaller lots, or by the whole volume of certain assortments, according to the kind of sale in question.

Sale by detail is the most rational mode of sale, as the lots have been estimated in quantity and quality, and their value can be accurately determined. It presupposes, however, the certainty of recovering from the purchasers all the cost of felling, conversion and removal of the material. Wherever there is a fair demand for wood, this is the mode of sale usually followed in Germany, Austria, Hungary, Switzerland and some other European countries.

(b) **Sale of Standing Trees.**

The sale of standing trees involves the sale, or at least, the fixation of the price, before the wood is felled. This may imply the sale of the fall of timber on a felling-area for one year, either **by single trees**, or by the **whole felling-area**; or of the **principal yield of a forest for a term of years.** Where the fall of timber during a single year is sold, two methods are in force according as the felling and conversion is done **by the owner**, or **the purchaser.**

i. *Conversion by the Forest Owner.*

Sale by unit of produce implies that the felling, conversion and clearance of the felling-area is done by the forest owner, it therefore closely resembles sale by detail, differing from it only in the fact that the prices are fixed for each wood-assortment before the trees are felled, and that the purchaser contracts to pay at rates previously agreed upon for all the wood of the assortments he has bought.

Such sales are at present frequent in Germany, Austria-Hungary, Switzerland, France, &c. They usually extend to the produce of a whole felling-area, and the fellings may be of any character, as neither sylvicultural interests nor the revenues of the forest are prejudiced by the mode of conversion. As the prices are fixed separately for each wood-assortment, and for different classes of assortments by the unit of cubic contents (cubic meter), an approximately correct estimate of the real value of the yield is secured. When experience of the results of former fellings does not guide the owner (by taking percentages) as to the volume and quality of the crop, the probable produce from each tree should be calculated separately, and an estimate thus made of the volume and quality of the yield of the whole felling-area. It is, however, evident that no guarantee should be given to the purchaser of the exactness of this estimate.

Where this mode of sale is applied to single trees (as, for instance, large oak-trees) and not to entire felling-areas, a better forecast of the real value may be obtained.

ii. *Conversion by the Purchaser.*

When trees are sold standing and the purchaser undertakes their conversion into timber and firewood, if the seller and purchaser are not to be quite in the dark as to the real value of the trees, a much more careful forecast of the yield should be made than in sales by unit of produce; if this is not thoroughly well done, the forest owner will certainly come out of the business at a loss.

These sales may deal with **all the standing trees on a felling-area** or on a demarcated portion of a felling-area. In such cases, the estimate of their value depends on an accurate survey of the area, and a calculation of the average yield of an acre, which is possible in the case of homogeneous woods, such as pure coniferous even-aged woods, or coppice. Care must then be taken, in case experience of the yield of similar fellings is not available, to make use of every assistance which the different methods of valuation can afford. In Russia, crops of standing trees are generally sold **by area** [and so is coppice in England.—Tr.]

If, however, the sale is only of certain **marked trees on a felling-area**, the protection and tending of the forest may be much more endangered than when the sale is by area. This is specially the case in regeneration- or selection-fellings, and in those of trees standing over poles. This mode of sale may however be advantageously applied to standards over coppice, or to isolated large trees in middle-aged high forest, or in forests where the trees are far apart, as in Russia. It is more admissible for conifers than for broad-leaved species, as the real value of the former may be more accurately forecast than broad-leaved species, which so frequently suffer from internal defects.

Here and there material of little value, the conversion of which would prove too costly for the forest owner, may be sold *en masse*, such as stunted wood on waste land, inferior pollards, stumps of trees which are difficult to uproot and split, &c. A purchaser who estimates his own labour at a low value may find a profit in purchasing such material.

iii. *Lease of the Yield of a Forest for a Term of Years.*

The two preceding modes of sale involve the sale of only one year's fellings in a forest, but not the lease of the annual yield of a forest for a term of years. This was formerly almost the only mode of sale in the vast Austrian mountain-forests. During the eighteenth century, nearly all extensive works using wood obtained the assignment of adjoining forests for their exclusive use, sometimes with the sole stipulation that the management of the works should remove all the trees in a forest during a rotation, on undertaking to pay all the costs of maintenance of the forest. This privilege was termed *Kohlwidmung* (charcoal concession), and implied the right of the works to take so much charcoal annually from the forest. Such concessions of forest produce are no longer made, but leases of forests for terms of three to ten years still prevail, chiefly in Russia, Sweden, West and East Prussia, in some provinces of Austria-

Hungary (Moravia, Bohemia, &c.), Switzerland, &c. The price is then fixed by formal written agreement. Some of the older concessions are not yet abolished, in spite of repeated endeavours on the part of the German Forest Departments and private forest owners.

iv. *General Remarks.*

The chief point to be observed in all sales of standing trees is to decide the requisite sylvicultural and protective conditions and to word them clearly; a thoroughly detailed description of the material to be sold should also be given. In France, lists of trees to be sold standing are published in pamphlet-form giving all the sale-lots on the felling-areas of a single forest range (*inspection*) for a whole year.

[In these French lists, besides the number and species of trees in each lot and their cubic contents in timber and firewood, a list is given (*cahier des charges*) of all the protective works to be done at the expense of the purchaser, such as pruning, planting-up blanks, repairs to roads, &c., together with estimates of their cost. Strict general sylvicultural and protective rules for the conduct of the fellings are also printed in each pamphlet.—Tr.]

In Austria, also, much acuteness has been shown in devising the conditions of sale of standing trees.

2. *Various kinds of Sale.*

Three kinds of sale of forest produce are in use, which depend on different methods of fixing its price; namely, **sale by royalty, sale to the highest bidder and sale by private contract.**

(a) **Sale by Royalty.**

Whenever wood of any assortment is sold at rates fixed by the forest owner, the mode of sale is termed **sale by royalty**, or sale at **fixed rates** or **tariff-prices.** The characteristic of this mode of sale is that the price is fixed by the seller, the forest owner providing for the distribution of his forest produce among its consumers.

i. *Mode of fixing the Royalty.*

By the term **royalty** is meant the present local value, in a forest district, of any wood-assortment, as it is determined by the free action of demand and supply in the timber-market and in auction-sales. The royalty for any assortment is determined by taking the average price during a recent period for all similar wood sold within a certain district. The larger the volume of wood sold in the open market, and the narrower the limits of time and place within which the average price is fixed, the more nearly will the royalty correspond to the correct price of the assortment.

Royalties were formerly fixed on quite different grounds from these. Up to the end of last century it was considered advisable—and in some countries this is even still the case—that the State, at any rate, should sell the produce of its forests at moderate rates to the people. Royalties were therefore purposely kept low, so much so, that they were considerably under current local prices ; they therefore formed the minima margins of the prices of forest produce.

Royalties were fixed for a district by making benevolent estimates of prices, after considering the area of the district which was under forest, the economic condition of the population, the cost of transport, and, finally, the different qualities of the wood-assortments. It was, therefore, a mere stroke of luck if the royalty was anywhere near the correct price of an assortment. How little, indeed, this was the case, may be gathered from the fact that royalties were often fixed for entire provinces, or small States, and frequently remained unaltered for long periods. If the forest officials desired to counteract these bad results to some extent, they had to propose an increase in the royalties for certain special cases, and thus attempt to reform an evil by imposing a greater one. This system did most damage in Austria, where certain State and private forests were assigned to mines of salt and other minerals, supplying them with forest produce at prices which were for the most part ludicrously low, often so much so as barely to cover the cost of maintaining the forests. In this way, forests were deprived of their proper revenues, and their maintenance and development were unfairly hindered.

The great harm done to forests by low wood-prices, the rising value of all raw material, the constantly increasing demands on State treasuries and the many inconveniences resulting from the above antiquated ideas in the sale of forest produce, have, in most countries during the second and third decades of the present century, led to a complete change of principle. It is now admitted that the forest owner, like any other producer, is thoroughly justified in selling his produce for its full value.

Even if there can be no question that the price of firewood depends on that of coal, yet to depress it as low as that of coal merely on this account is not fair, for there are several other intervening circumstances which must not be neglected, such as custom, comfort, &c.

The price of wood varies with time and place and in order to allow due weight to these factors in fixing royalties, different tariffs must be assigned to different districts or sale-depots. Thus, all places where wood-prices are about the same, should be comprised within a sale-district, excluding places where there are any marked differences in prices. In a province, forest district, or forest range, therefore, there will be as many tariffs as there are market-values for the same wood assortment. But even the very points which have occasioned the separation of sale-districts from one another may themselves vary, and render it necessary to alter the circumscriptions of the latter. In a similar manner allowance is made for periodic variations in wood prices, by revising the tariffs whenever a general rise or fall in prices has occurred. Owing to the present changeable nature of trade this should be done almost every year, at any rate for sale-districts within the reach of the general trade in wood. As regards very valuable wood-assortments, tariffs should be revised even more than once a year, whilst for inferior assortments longer intervals, from two to three years, will suffice.

Where most of the annual yield of a forest is sold to the highest bidder, tariffs are prepared for the ensuing year by taking the average sale-prices in round numbers for each assortment, due allowance being made for any abnormal circumstances affecting particular sales, or for assimilating the tariffs sufficiently to those in force in neighbouring sale-districts. Whenever the average results of sales to the highest bidder do not afford sufficient data for framing tariffs, the market-prices of wood in neighbouring towns should also be utilized, naturally after deducting the cost of transport from the forest depots.

In many cases, the forest range will suffice as a sale-district. It may, however, be necessary to subdivide a forest range into two or more sale-districts, *i.e.*, to fix several tariffs in a range according to the different directions in which the produce is distributed. This is generally the case with ranges situated on the borders of extensive forests, or composed of widely scattered isolated forest blocks, and where considerable differences of prices result from different transport charges. In high mountain-regions, especially the Alps, tariffs will depend on the altitudes of different zones of forest; thus, the lowest zone, including the valleys, may form one sale-district, the middle zone, another, and the highest forest zone, with Alpine hamlets, cheese-factories, &c., the third.

As a rule, royalties include the cost of conversion and removal from the felling-area. In districts where the conversion and removal of the wood is partly done by the purchaser, two tariffs will be in force, including or excluding the above charges.

ii. *Application of the Method of Sale by Royalty.*

There are districts where, in consequence of admitted rights, almost the whole annual yield of forests in firewood is disposed of by royalty, either at a full or reduced value; in other districts this happens in the case of only a portion of the yield and no further than sheer local necessity requires. In most cases, however, sale at tariff-prices has receded quite into the background, and is resorted to—in cases of **unforeseen distress**; for **wood-assortments which cannot be sold to the highest bidder**; for **inferior sale items**, the sale of which will not repay auction charges, or **rare assortments** of specified kind and shape; also finally, in some districts, for the **requirements of the forest officials**, who are not allowed to bid at auctions.

In country districts, it is chiefly wood for agricultural requirements, such as bean-sticks, tree-props, &c., which in cases of considerable demand should be sold by royalty, as in this way theft may be prevented.

It may be imagined, since sale by royalty is at present generally the exception, that the fixation of a correct tariff is a matter of only second-rate importance. This is, however, not the case, for a continual knowledge of the actual value of forest produce is advantageous in many ways. Royalties are the best means of deciding the acceptance of offers to purchase wood, or when to knock-down lots to bidders at public auctions; they afford a means of estimating the value of stolen produce; they are indispensable in every kind of forest valuation, and in calculating the value of forest rights, damage, sale of forest land, or other similar questions, and finally in calculating budget-estimates and other statements.

Royalties are evidently useful only when they represent the actual momentary local value of wood, *i.e.*, its average market price for the time being. Unless this can be affirmed of them they are absolutely worthless. It must not, however, be forgotten, that royalties also possess the character of **prices fixed by authority**, and thus often exercise an influence on market-prices which is not always justifiable.

(b) Sale to the highest Bidder.

The next mode of sale to be discussed, is when a purchaser offers his wares for sale to the highest bidder in the presence of a larger or smaller number of purchasers. The characteristics of this method are, that the price is fixed by the purchasers, and the wares, *i.e.*, the forest produce, is divided among the consumers according to their own requirements and without direct interference on the part of the forest owner.

Sale to the highest bidder may be effected by **public auction** or **sealed tender.**

i. *Sale by Public Auction.*

(*a*) **General Account.**—Public auction-sales may be conducted either by the purchasers out-bidding one another, or by putting up each sale-lot at a prohibitively high figure, a public crier then calling-out at regular intervals successive reductions by a fixed sum of this figure for any lot, until one of the purchasers signifies his acceptance of the lot at the last figure proclaimed by the crier. This latter mode of sale is termed a **Dutch auction,** and in case two or more purchasers accept a lot simultaneously, it is put-up for sale to the highest bidder among them.

Sale by successively increased bids is the common mode of auction-sale in Britain, Germany, Austria-Hungary, Switzerland, &c., whilst Dutch auctions for forest produce prevail in France, Belgium, Holland, Alsace and Lorraine.

Dutch auctions for forest produce are generally employed only in the case of valuable timber sold in large lots, and when only a few of the purchasers present are men of means ; they are preferred in Alsace. Wherever wood is sold in small lots to a number of small purchasers, such a method would be out of place for the following reasons, it takes much more time than when purchasers outbid one another ; where there are a large number of purchasers assembled, only a few of them will have the requisite presence of mind to make a bid at the right moment ; customary usage may be against this mode of sale.

[Dutch auctions are preferred in France in the sale of standing trees in the principal fellings, because there are a body of large contractors, termed *adjudicataires*, who make it their business to purchase the marked trees standing on a felling-area, and convert and remove them for sale to smaller dealers or industrial enterprises. These men visit every felling-area within their beat, measure and estimate the value of every marked tree ; they know exactly what amount they can afford to pay for the trees and bid accordingly. French foresters consider that Dutch auctions prevent the purchasers from agreeing not to out-bid one another ; a purchaser cannot know beforehand at what figure any other purchaser will buy, and therefore dare not delay too long in his offer to purchase, fearing lest the lot should fall to another person. In France the felling-areas are subdivided into small lots, which are marked out on the ground ; no lot should exceed 10,000 francs, £400, in value.—Tr.]

β. *Procedure in Auction-Sales of Wood.*

When once the mode of disposal of the produce of a felling has been decided, the produce which is to be auctioned should be carefully valued without loss of time. The **date** of the auction should then be fixed, and this, as well as **the place** where the auction will be held, and **the list of material** to be sold, should be **publicly advertised.** The procedure of the auction itself begins by an announcement of the **conditions of sale** made to protect the seller against injury or loss, the lots are then put-up successively at the fixed upset-price, and knocked down to the highest bidder ; the highest bid is therefore the price of each lot. As soon as the last lot has been sold, the **auction is concluded** by ascertaining the total price paid for each wood-assortment, and for the whole of the produce which has been sold.

The success of the auction will depend in some measure on **the place where it is held.** This may be either on the felling-area or at the wood-depot, or in a building in some neighbouring and suitably situated village or town.

If the sale is effected in the forest or depot, then every would-be purchaser can examine each lot, and estimate its value, and bid for it with confidence and deliberation. This is particularly useful for purchasers when there is a considerable difference in the quality of the various lots.

When, however, in a sale by detail, the lots are scrupulously assorted, as at present in many forests, the buyers are accustomed to visit the felling-area before the sale and true descriptions of the lots are given by the auctioneer—or where in sales of standing trees sufficient information regarding their volume and quality has been supplied beforehand to the buyers—a sale under cover of a roof is preferable, as it is much more expeditious and usually attracts a greater number of purchasers than a sale in the open air. Anyone wishing to purchase a large quantity of timber, will in any case visit the felling-area before the sale, and small purchasers have no time during the sale to measure and value every log, without intolerably delaying the auction. An auction in the forest is therefore advisable—when buyers cannot be induced to visit the felling-area or depot beforehand; when the wood has been carelessly assorted, or each lot contains wood of various assortments and qualities. In all other cases, the interests of the forest owner are generally better safeguarded when the auction is held in a building.

The **date** chosen for the auction; the **place** in which the auction is held, and the **list of material** to be sold, should now be **publicly advertised**, both in the best local newspapers and in printed notices posted-up at inns and public buildings in the sale-district, as well as by the public crier. If the produce to be sold is chiefly wood for local demands, it is superfluous to spend much money on advertising; it is then sufficient to give a list of the chief assortments in the notices, and to advertise only in purely local newspapers. If, however, valuable timber is to be sold for which there is a good demand or which is suitable for export, or in sales of large quantities of merchantable firewood and especially of standing trees, the sale notices should be more widely published. In such cases the forest manager should select the best newspapers for his advertisements, and too much economy would be out of place. Whenever purchasers from a distance may be expected, they should be informed by advertisements of the chief conditions of the sale.

Whether the sale should be conducted by Forest or Accounts officials, depends on the special administrative arrangements of different countries. Although unnecessary expense in this matter cannot be justified, it is, on the other hand, undesirable to leave all responsibility for the sale to the Forest Department. The Accounts officials are, in any case, better acquainted with the buyers than the foresters and should therefore be responsible for their solvency; this is the case in Prussia, where the Forest Accountant attends all State forest auctions.*

The auction commences by an official reading out and explaining the **conditions of sale.** These include: a statement whether the sale is with or without reserve; the terms of security for payment to be offered by the purchasers; conditions under which unknown strangers are allowed to bid; measures of security against a conspiracy among the buyers to keep down prices; dates of payment, and limit to which credit is given; a list of roads by which the wood may be removed, and the conditions of removal; special political and sylvicultural conditions which are considered advisable; finally, that no complaint will be entertained as regards any lot after it has once been knocked down.

The **upset-price** at which the lots are offered for sale must evidently be less than that expected from the purchaser. How much lower it should be is a question not without importance as regards the obtainable price. Too high an upset-price frequently prevents the purchasers from bidding freely; when too low, it causes delay, and if the competition is limited, leads to inferior prices being obtained for the wood. Although local circumstances, the social condition of the purchasers, their number, and several other matters, may influence the choice of an upset-price; in most cases, it should be 10 to 20% under the royalty or real value of the wood. In the case of valuable merchantable timber, the upset-price may be higher, and even equal to the royalty when there is a probability of eager bidding. In the administration of some State forests (Saxony and Baden), the practice of fixing an upset-price to the lots in proportion to the royalty has been discontinued; unrestricted bidding being considered more advantageous to the owner, as well as to the buyer.

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* [In France, the *Préfet* or *Sous-préfet* presides at State forest auctions. In Belgium, sales of standing trees in private forests are conducted by a *Notaire*, or notary public, who charges 11 % commission, 3 % of which is a State tax, and guarantees the solvency of the purchasers. In France, the charge is 15 %.—Tr.]

Every sale-lot should be clearly designated in the sale catalogue by its number; the assortment, volume or dimensions of the wood, and any other particulars which are advisable being given. In important timber-sales, intending purchasers should be allowed, before the sale, to consult the felling-register, or facsimile extracts from it should be handed round. In sales of standing timber, ready assistance should be given to enable purchasers to obtain knowledge of their value. The amount of the highest bid for each lot, with the purchaser's name, is then entered in the auctioneer's report, or in the felling-register. This is often attested by the purchaser's signature and that of a trustworthy surety. In sales by detail, after the last lot has been sold, the price of the different assortments is totalled and the average price of each assortment calculated, so that it may be decided whether the confirmation of the sale may be at once effected, or must be postponed, in case the average prices of the assortments are under the royalties* at which the forest official is authorised to sell the wood. In case the prices are lower than the authorised minima, they must either be confirmed by superior authority, or a fresh sale held.

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* A sale may be confirmed in Baden, when the average price offered is not less than 10% lower than the average price of the last sale in a neighbouring forest range. In Prussia, the *Oberforster* can confirm a sale, if prices are not 20% lower than fixed royalties. In Bavaria, the *Forstmeister* sanctions annually the percentage by which sale-prices may fall below royalties (for timber, generally, 10%, firewood 15%.)

γ. *Delivery of Wood to the Purchasers.*

The sale having been confirmed, the wood of the different lots is delivered to the purchasers immediately after the sale, unless there is any difficulty in furnishing security for payment. If the sale is held in the forest, this is done either by handing over the wood at once, and by giving each purchaser a written order of removal for the wood he has bought. When sales are not held in the forest, the forest manager assembles all the purchasers at the felling-area or depot, on a day fixed as soon as possible after the sale, and shows each purchaser his wood. Either then, but generally at the auction, each purchaser obtains his **permit to remove** his wood, on which is stated—the place where the wood is lying, a sufficiently clear description of the wood sold, the price to be paid for it and sometimes the dates when payment should be made. This permit should then be taken to the forest cashier and the price paid to him, when it is returned stamped and receipted, and the purchaser can then remove his wood. When credit is given, and payment is therefore not immediate, the forest cashier should notify to the forest manager the names of any purchasers regarding whose solvency he has any doubt; in such cases, the wood must remain in the forest until payment has been made, or satisfactory security provided.

Sometimes a period of time is fixed during which the forest manager is responsible for the safety of the purchasers' wood lying in the forest.

As a rule, however, wood once sold and delivered to the purchaser remains at his risk after he has received the permit for its removal, although the forest guards are expected to watch it carefully and prevent fraud. In many districts—as, for instance, in the Rhine-valley—the forest owner declines all risk for the sold wood, but a special guard is appointed and paid for by the purchasers for one or more felling-areas, to protect their wood when lying in the forest. A fixed rate of payment is then allowed for every stack of wood, every log and every hundred faggots, which is paid to the guard by each purchaser on the removal of his wood. This institution of a guard for felling-areas is generally tacitly agreed to by all purchasers of wood. Usually, the men who stack the firewood also guard the felling-area, and they can conveniently carry on these double duties.

ii. *Sale by Sealed Tender.*

The other mode of sale to the highest bidder is that in which, after public advertisement of a sale, the offers or **tenders** to purchase are written and submitted to the seller in a sealed cover. In the case of a sale of standing trees, the written tenders to purchase may be either for the produce of a whole felling-area, or for separate lots; in either case a valuation in volume and by assortments of wood is presupposed. If the wood to be sold has been converted, it is generally sold in assortments, or classes of assortments, usually by the purchaser tendering so much °/₀ more or less than the upset-price (say, two, five, ten °/₀ over, or under, the usual royalty). All tenders which have been received are opened on a fixed date and hour, in the presence of the intending purchasers. They are publicly read out, and each lot awarded to the purchaser who has submitted the highest tender, provided he can give good security for payment.

Just as the solvency of the persons who tender for the wood must be assured, so other motives such as sylvicultural requirements may also influence the sale. As a rule, however, the sale is confirmed to the highest bidder. As in sale by public auction, it is highly in the interests of the seller and an absolute right on the part of the purchaser, that before tendering he should have free access to the sale-lots, and, on demand, should be allowed to see the report of the valuation of the wood and the felling-register.

(c) Sale by Private Contract.

When an owner deals with a single purchaser, and the price is fixed after a discussion between them, a sale by private contract results. This mode of sale is characterised by the fact that the price is fixed by both buyer and seller.

In arranging the price, the owner will generally be guided by the average results of past sales to the highest bidder (or in certain cases may accept this figure as the price).

Sale by private contract has the advantage of saving expense in valuation and auction-charges, or in avoiding possible loss. At the same time, it is clear that the seller undertakes a greater responsibility than in any other mode of sale, and must have a precise knowledge of the actual state of the wood-market for the time being.

3. *Comparison of the various Modes of Sale.*

Each of the above methods of selling forest produce is advisable under certain special circumstances; it is better that a forest manager should not be wedded to any one of them, but that he should be ready at any time to adopt whichever method may prove most suitable for the case in question.

(a) **Sale by Royalty.**—Sale by royalty has the least claim of all to exclusive adoption or even preference, as has been already shown on p. 452. Only in some places, in the case of certain privileged demands for wood, is such a method exclusively followed, and then the formation of a proper tariff demands great care. Where, on the contrary, sale by royalty is only occasionally followed, it forms a useful supplement to other modes of sale. It has then the advantage, in cases of necessity (conflagration of a village, scarcity of wood for agricultural purposes at seasons when the principal sales are not conducted, &c.) of satisfying urgent demands. Also, when traders combine to keep the price of forest produce below its full local value, a recourse to sale by royalty may improve matters.

To adopt sale by royalty generally and exclusively would at once exhibit the shady side of this method, and prove that it is almost impossible for a forest manager to acquire an accurate knowledge of the real local value of wood. If it were also argued that prices may be corrected by the competition of sellers, a reply may be made that forestry is less able to effect such a result than any other industry, the forests in any district being usually in the hands of one or only a few owners.

(b) **Sale to the highest Bidder.**—Sale by public auction, provided that enough competitors are present, may be considered as the most ordinary mode of sale. The chief advantages and disadvantages of its different varieties are as follows:—

i. *In Sale by Detail.*

When converted timber is sold in small lots by public auction, sufficient competition will ensure the best prices, for owing to demand and supply, prices in this case most nearly represent the true local value of any sale-lot, including its quality, utility, portability, &c. By auctioning forest produce, it is distributed in the simplest manner, and according to the measure of their requirements, among the consumers. If there are exceptions to this rule, they are less numerous and more easily remedied than in sales by private contract. Much less time is occupied by auction-sales than by sales by private contract, a matter of great importance. All unjust dealing and respect for persons which may easily occur in private sale, or complaints of which may be brought against the most honourable foresters, are avoided by public auctions. The superiority of public auction over sale by private contract is proved by the fact that nearly everywhere in Germany, sale by private contract has been supplanted by auction-sales.

Amongst the disadvantages urged against sale by public auction, the following is worthy of notice, namely, the possibility of the purchasers coming to an understanding before the sale. This is especially to be feared—when the attendance at a sale is small; when too much material is offered for sale at once; in the case of wood-assortments which not everyone can buy, either because their cost is prohibitive, or demands for them are small; or finally, when the seller purposely tries to maintain prices above their proper local figure. Coalitions of purchasers are very frequent in the sale of merchantable timber, rafted wood or firewood intended for trade, for which local competition may be nil, or of a very limited nature.

Coalition of purchasers is becoming a common affair in Germany, being much more frequent than is imagined both at large and petty sales. The theoretical idea of an auction-sale involves the assumption that every competitor is present merely on his own account, and that a coalition among the competitors is impossible: coalition cannot, however, be prevented, provided it is agreed upon freely by the competitors; it is illegal only when brought about by threats, &c. The seller must, therefore, endeavour to guarantee himself against the damage he may suffer owing to coalition at auctions. Almost the only remedy available is to stop the sale, and adopt measures to improve the competition of purchasers. Among these are the following: advertising widely (this however, presupposes sufficient wood to attract distant purchasers); sub-division of the sale-lots into smaller ones, so that it may be possible for poorer purchasers to compete; finally, avoidance of all burdensome sale-conditions which reduce competition. A further measure against coalition is to adopt another mode of sale.

There are also first principles of justice as well as of self-interest, which should always induce the seller to avoid all conduct on his part which may hinder a proper price being paid, or lead to coalitions of the purchasers.

ii. *Sale of Standing Trees.*

The sale of standing trees, especially with the right of felling and conversion by the purchaser, is frequently preferred by wood-merchants and large dealers in timber to that of converted wood. This is easily explained by the fact that in the former case the wood-merchant can convert and remove the wood more profitably to himself, and can time its conversion and removal so as to take advantage of any special demand. In this mode of sale, however, the purchaser obtains the crown and stumps of the trees, as well as the stems, and thus may be encumbered with a quantity of firewood, the disposal of which is often burdensome and unprofitable to a timber-merchant.

The matter has a different aspect as regards the interests of the forest owner. When the standing trees are sold by **unit of produce**, this protects the forest owner from the necessity of selling his trees at too low a price, and at the same time allows him full play in carefully felling and converting the trees. When, however, it is important to satisfy local demands, this mode of sale is not satisfactory [as the whole of each assortment from a felling-area (or the demarcated portion of one) is necessarily purchased by one individual.—Tr.].

Sale of standing trees to be **felled and converted by the purchaser** is generally more disadvantageous than otherwise to the forest owner, since he is obliged to hand over the felling-area more or less to the purchaser, and is unable to effect an accurate estimation of the volume or quality of the wood, a condition which is generally more unfavourable to the seller than to the buyer. It is well-known what large profits are made by wood-merchants in the purchase of whole forests, or compartments, of standing trees in Russia, Bosnia, Hungary, &c. Still, under certain circumstances, the sale of standing trees may be preferable to that of converted wood, especially when the wood-market is over-stocked ; also when supervision is defective or labour scarce, and in districts where this mode of sale has become customary, and long usage, influenced by the interests of both buyer and seller, have removed much of its harmfulness.

Experience of the sale of standing trees has shewn, especially in Russia, where this mode of sale prevails, and also in France * and Austria, that in many cases sylvicultural requirements cannot be safe-guarded to the extent that is desirable in regular forest management, even after most carefully specifying the conditions of sale and the best possible supervision. In extensive forests, and where the regeneration and culture of a forest in no wise depends on the mode of utilization (as in clear cuttings) there is no objection to the sale of standing trees. If, therefore, sylvicultural considerations do not intervene, it may be to the advantage of a forest owner, under certain circumstances, to adopt this method temporarily. Such circumstances are—persistent coalitions of competitors at auctions, and scarcity of labour, for wood-merchants can often engage wood-cutters more cheaply than the Forest Department. Since a wood merchant, with foremen attached to his interests, is more in touch with the whole business than the distant and often impersonal forest owner, the felling, conversion and assortment of the produce of a felling-area is effected with more zeal and skill, and a finer finish is sometimes given to what would otherwise be merely rough conversion.* Finally, in the case of extraordinary quantities of produce, owing to damage by storms, insects, &c., when the trees may be considered as only partially standing, it may be more advantageous to the owner to sell the trees on the whole affected area to a wood-merchant, than to convert it by the help of his own wood-cutters, and sell the material by detail.

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* [The attention to sylvicultural requirements on felling-areas in the French State Forests on the part of the *adjudicataires*, or purchasers of standing trees, is generally satisfactory. In thinnings, where all the trees to be removed cannot be known before-hand, but are marked gradually as the work progresses, sales in France are effected by unit of produce.—Tr.]

As regards State forests and those belonging to corporate bodies, the question between these two modes of sale has another bearing. The forest official should generally pay maximum wages for felling, conversion and removal of the wood. When, however, in State forests from short-sighted financial economy, wages are kept so low that even the industrious wood-cutter can hardly earn a living wage, the work he effects must decrease both in quantity and quality, and he loses all interest in the well-being of the forest. The rich wood-merchant who undertakes to fell and convert the trees on a felling-area usually pays high wages, as his interest is bound-up with careful conversion, &c. That he carefully considers this expense in the price he pays for the trees cannot be denied. In such cases, the general welfare is evidently better secured by selling the wood standing than by converting it departmentally, the balance falling the other way for the forest owner. An example has here been cited merely to show that there are many factors affecting the question in any special case.

Sale by sealed tender should be employed for standing trees, or in sales by detail, for large lots of converted wood; it is especially suitable when only a few rich wood-merchants compete. It also serves as a remedy against coalition of buyers when trade is slack, and finally, in selling assortments for which there are no local purchasers, for instance, hop-poles, osiers, &c.

Whenever only a few large dealers are present at a sale, they can easily agree to keep down prices. By calling for sealed tenders the forest owner may invite competition from distant purchasers in order to paralyse the coalition of local traders; this remedy may, however, prove to be only of a temporary nature.

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* [In the Himalayan forests, export-works involving a large expenditure are required in order to work the forests economically and profitably, and the trees are simply converted into railway-sleepers or firewood; it has therefore proved more profitable, after agreeing beforehand with a railway or the commissariat department for the sale of the produce, to convert the trees departmentally rather than to sell them standing to purchasers, who are accustomed to work out standing trees from forests of native chiefs without any sylvicultural restrictions. —Tr.]

(c) **Sale by Private Contract.**—The sale of wood by private contract is employed when the demand is slack. There may often be only one or a few purchasers, and it is then preferable not to auction the produce, but to deal directly with the purchasers; the best price possible will thus be obtained, which would not result from selling to the highest bidder, where competition is so restricted. In this case also, the lots should be large, and the purchasers men of means. Sometimes the whole produce of devastated forest-areas are thus sold; sometimes an entire assortment—round billets, charcoal-wood for smelting-furnaces, large quantities of railway-sleepers, telegraph-posts, merchantable timber, &c.; sometimes large lots of converted wood, for which at an auction the bids were too far below the proper prices.

Sale by private contract has recently been extending in a remarkable manner, especially in North Germany, and desires for its further extension have been expressed. This may be justifiable for certain districts, but in most cases, and especially in sales of State forest produce, it should be considered rather as a necessary evil, enforced by a limited demand in slack times, than as an even tolerably regular mode of sale, for where trade is brisk, no forest owner would wish, by private sales, to reduce the competition at auctions.*

SECTION III.—BUSINESS PRINCIPLES INVOLVED IN THE SALE OF WOOD.

1. *General Account.*

Owing to the moderate net revenue resulting from forests, and the considerable amount of invested capital which they involve, it is evident that every forest owner should strive, by improving the markets for his produce, to obtain as high a price as possible for it. Even if the forest owner can exert no influence on the general temporary prices of wood, and as regards the sale of his own produce, is fettered by the situation of his forest, the state of the local wood market, and many other conditions; yet the financial results of the sale of his wood, under the given conditions, depend greatly on his skill in managing sales. Much has been already said on this subject in the preceding sections; it is, however, necessary to discuss, in a general way, the principles and experience of mercantile business which are most nearly related to the above objects.

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* [In Britain, coppice is generally sold at so much an acre, or the wood felled and sold in assortments after conversion. Standards over coppice are sold at fixed prices per cubic foot which increase with the girth of the tree; only the bole is cubed, and the crown given-in to cover cost of felling. In beech selection forests, the marked trees are usually felled by the owner, and the logs and faggots sold as they lie in the forest, and this is also the case with oak and Scotch pines in the Crown forests, the price being fixed by private contract.—TR.]

In order to sell wood profitably, a forester must be a trader, and must have the same aptitude for trade as other dealers who sell wares.

Forest officials entrusted with the sale of produce should either have mercantile experience, or endeavour to acquire it in a certain degree. Exactness in formally carrying out departmental orders and routine will not suffice here, for this is not by any means all that is needful for a commercial mental outfit. Active and intelligent intercourse with the world, especially in all industrial and mercantile questions, observation of all causes which affect the market for his own produce, persistent endeavours to detect all precursors of trade, to weigh accurately the importance of all intervening occurrences, and to form correct decisions after considering all these circumstances—only habits such as these make a successful trader.

2. *Genuine Goods, and good Weight and Measure.*

All solid mercantile success is founded on the genuineness of the goods offered for sale, and on giving the purchasers good weight and measure. Genuine goods are those which are equal to the description given of them by the seller. Every wood assortment should contain only pieces of wood which are thus correctly classified. Every offer of inferior wood, every concealment of defects and damage in timber, every classification of pieces above their proper class, and so forth, impairs their genuineness. Wood should therefore be always so exposed for sale that every would-be purchaser may easily ascertain its quality. In a similar way, full measure should always be given in firewood stacks, and a thorough understanding arrived at as to the sale measurements of logs, in order to maintain a good credit with purchasers.

A most careful assortment in accordance with prices inspires purchasers with confidence. With the same end in view, the price-tariff should also be most carefully compiled in accordance with the real value of the wood-assortments. Above all, timber should be carefully classed as regards its quality, and a forester should give no cause for a report that he sells half-rotten or inferior material as good timber. He should also take great care not to mix inferior wood with good material, hoping thus to obtain a better sale for the former.

It is now about time to secure uniformity in all wood measurements—especially should all timber be measured without its bark, and old country measures should give place to the metric system. Only absolute clearness in measuring leads to genuine trade. It frequently happens that in slack times for trade, logs are measured below their actual dimensions, or timber classified below its proper rating, with the object of finding ready purchasers at prices which appear to be on a par with, or even to exceed, the fixed tariff. Such manipulation must be entirely abnegated, for it impairs the confidence traders should feel in the honesty and accuracy of forest officials, hinders the compilation of a correct tariff, and serves only to blind superior officials.

3. *The Produce to be Sold.*

Every felling-area yields good as well as inferior wood. The forester should always attend most carefully to the conversion and assortment of good material, for this chiefly affects the financial returns of his forest; he should also endeavour as much as possible to avoid overstocking the market with inferior wood. This should be especially attended to when trade is slack, or the sale of good material will be prejudiced.

When the market is overstocked, it is better to leave stump-wood and inferior firewood in the forest than allow it to reduce the price of the better class of firewood; also, where poles from thinnings are in a similar condition, it is better not to classify them as timber. In slack times it is a matter of ordinary prudence to reduce to the utmost the cost of conversion of inferior material. Purchasers of such stuff will convert it more cheaply and more in accordance with their own wishes than forest officials.

In converting his trees, the forester should always be guided, as far as general rules will allow, by the wishes of purchasers. Whenever there is a generally expressed desire for any change in the details of the wood-assortments, as is often the case, the forester should be ready to meet the purchasers' wishes: they are usually the expression of an actual technical requirement.

When, for instance, there is a desire that stacked wood should be more than a yard long, or that butts should be longer than is usual in the locality, the question should be carefully considered, and it often happens that it is in consequence of a new demand for timber, and then the wood should in future be converted accordingly.

4. *Wood-Markets.*

A few decades ago, before the present world-wide means of communication had been established, each forest had its own local purchasers, its own more or less limited local market to which each forest range was practically confined. Only forests which were favourably situated as regards water-carriage were accessible to traders of the world-market, to which most of the best timber was floated. Matters have changed in this respect, and at present almost every forest range has a share in the world-market, and there are few forests too remote to feel its fluctuations. Although the local market has not entirely lost its importance in certain forest districts, yet, especially as regards timber, it is the world-market which regulates prices. Under these circumstances, the really enterprising forester must know not only his local market, but should also keep in view all the movements and changes of the world-market; although he may be only indirectly connected with the latter through the middleman, yet he should be thoroughly acquainted with the prices which prevail in the distant principal market, as well as those of the local market.

The generally isolated residence of forest officials would be an insurmountable obstacle in the way of his meeting such demands, were he not to avail himself of the assistance which is open to every trader. This consists in the public press and in consular reports from the chief timber-markets. As regards pamphlets dealing with the timber-trade, some are edited and distributed by the chief forest officials in certain States; others are private undertakings, for instance, *Das Handelsblatt für Walderzeugnisse*, the Berlin *Centralblatt für Holzindustrie*, *Revue des Eaux et Forêts*, *The London Timber Trades Journal*, &c.

Agents employed by forest owners and State consulates would do great service if they would publish, not merely periodic reports, but any rapid changes in the markets. The future can only decide as to the extent to which forest owners, like other wholesale producers, can make use of regular travelling agents to offer their produce for sale, and arrange contracts and deal with purchasers, &c.

It need hardly be remarked that all endeavours which may be made to raise the price of wood (since its fall in 1865) should apply only to timber, for, with exception of a few country districts, it is impossible to rehabilitate firewood in competition with coal. As long, however, as firewood is procurable at a steady and moderate price, it will always find a ready sale.

Although the fullest attention should be paid by the forester to the general market, he should always endeavour to improve and extend his local market. Wherever industries using wood, such as sawmills, factories for wood-pulp, furniture, carved work, &c. exist, or are to be introduced and extended, provided there is no sylvicultural impediment, they should be energetically supported and assisted.

5. *The Timber-Trade.*

Under present conditions, the assistance of the wood-merchant is, in most cases, indispensable to the forester. No wholesale producer can dispense with the middleman; least of all forestry, with its voluminous and heavy produce, its unequally distributed producing localities, and its owners, who are in general unfitted for trade (the State, municipalities, hospitals, &c.). As far as concerns the local market, and in cases where the latter favours a direct dealing between consumer and forest owner, the wholesale timber-merchant does not intervene. The petty dealer is, however, a necessary and generally welcome member of the local market. Whenever large quantities of wood, and especially of valuable timber, are in question, especially in forests with a small local demand, the wood, for the most part, would rot *in situ* if wholesale timber-merchants did not undertake its sale and distribution in distant districts which are densely populated and poorly supplied with forests. Forest owners and wholesale timber-merchants must therefore work hand-in-hand, and good business relations between them are entirely in the interests of forests, as long as only through the latter the distribution and conversion of the raw material into marketable produce can be effected.

Under present trade conditions, so changed compared with the past, it would be a serious injury to a forest owner were he to refuse to acknowledge the necessity of the middleman; he must, on the contrary, constantly endeavour to improve his relations with him. For it is the timber-trader who endeavours to extend the present market and to open out fresh ones and improve the means of transport; who invests a large capital in buying timber and establishing sawmills; who follows with attention every change, however small, in the price of wood; who is constantly posted-up in all industrial changes in the conditions of transport or the incidence of taxes, and who is vigorously engaged in pushing on the timber business. All this energy of the timber merchant, even though it is in his own interest, should be thankfully acknowledged by the forester. But if these desirable relations in the interests of both parties, between the forest owner and the timber-merchant, are to bear useful fruit, the latter must also be more ready than is often the case to meet the former half-way.

6. *Modes of Sale.*

Public auction of converted wood should be considered as the regular, though not exclusive, mode of sale, for it is only suitable when free competition of purchasers may be expected. In slack times of trade and when markets are overstocked, also in the case of very large fellings, sale by sealed tender, by unit of produce or by private contract, may yield better financial results than auction sales under such conditions. Wherever, business being very slack, large quantities of wood must be sold in remote and comparatively inaccessible districts, the forest owner may have recourse to sale of standing trees by area. Whenever it is possible, however, auction-sale of converted wood is preferable.

After considering all local and temporary objections to any mode of sale, there can hardly be any difficulty in deciding which to adopt in any particular case. To act by routine in such a matter may cause great pecuniary loss, as experience has often shown. Especially in selling valuable timber, the forester should not be guided solely by custom, but should select, without prejudice, whichever mode of sale is best for the case in point.*

7. *Season for Sales.*

The season when trade is most active is clearly the best time to sell the produce. As a general rule, autumn, winter, and early spring are the best seasons for the sale of wood ; matters vary locally in this respect, and the best seasons for sale depend on the necessities of the consumer, the dates of final payment for the wood, and the amount of leisure which the public interested in the purchase of wood can command at different seasons of the year ; also, as regards merchantable timber, on the usual date when contracts to supply the timber are closed, and the season in which, according to local custom, wood prices are steadiest.

Demands for firewood are clearly greatest in winter, whilst building and industrial timbers are more in demand during the summer. As, however, nobody burns green wood, but allows it, in any case, to dry throughout the summer so as to ensure a profitable sale, it is better to sell the produce of summer-fellings in the autumn, and those of winter-fellings early in the spring. In years with prolonged cold winters, evidently the best time for selling firewood is in mid-winter, and then cart-transport is readily available. Small wood for agricultural purposes, which is generally brought into use immediately after felling; railway-sleepers, which are sold by wholesale merchants and must usually be impregnated and delivered to the railway authorities by the beginning of summer, and other wood-assortments which are required early in the year, should be sold during autumn or early winter. When trees are sold standing, the sales should be effected in September, so that the merchant may know in time what business he has to undertake during the felling season. If the technical requirements for certain woods prescribe that the felling should take place in the growing season, an enterprising forest owner will endeavour to meet such a demand. The date of final payment for the wood sold is also more important than the immediate demand. Where sales are for cash down, they should be held in autumn and early winter, when the country people have most ready money; if payment is by instalments, with security, the season for sale is less important, provided the interval before final payment, for which autumn is best, is not too short.

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* [The Deputy Surveyor reports that in the Forest of Dean, trees are felled and sold in logs and butts as they lie. Any considerable quantity of timber is sold by sealed tender, and smaller or inferior lots by private contract, at so much a cubic foot for timber, varying with the girth, or in cords of 128 cubic feet.—Tr.]

When the peasantry takes part in wood-sales, these should be fixed when they have leisure to attend, and that is usually during winter. As regards wholesale traders, they generally sell from timber-yards, where they keep their wood a longer or shorter time, so as to profit by favourable opportunities for sale. The petty dealer, on the other hand, buys only at favourable seasons, when he can readily dispose of his wood for a fair profit.

The above remarks may be thus summarised :—Autumn and winter, and the times nearest to them, are the most profitable seasons for selling wood; by the middle of April, in ordinary years, the chief produce of felling-areas should be sold. It should also be noted that people become accustomed to fixed dates for sales, conduct business accordingly, and attend such sales with the determination to purchase sufficient wood for their requirements.

[In India, the sales of standing trees and other produce from the State forests between the Jumna and Ganges rivers, are held annually in September, so that work in the forests may commence in November, as soon as the healthy, dry season has commenced.—Tr.]

Whenever large falls of timber result from storms, snow-break, or damage by insects, the sales should be hurried-on and the wood rapidly cleared, even if only inferior prices are obtainable; for the loss by the threatened decay of the wood is, as a rule, greater than that due to a low price for it, whilst danger of further damage by insects is reduced.

8. *Extent of the Sales and Sale-Lots.*

The quantity of wood offered for sale should correspond with the number and position of the purchasers. In well-populated districts, with a fair consumption of wood and to satisfy local demands, under ordinary circumstances, a moderate supply of converted wood, say 600 to 1,200 cubic meters (400 to 800 loads) of timber and firewood usually sell better than larger or smaller quantities. In poorly populated districts with a small local demand for wood, and with large quantities of wood for sale and only a few wood-merchants competing, large wood sales are absolutely necessary. Whether in such cases the produce of several ranges, or of several felling-areas, should be sold together, depends on the expected amount of competition. In no case should valuable timber be sold at different times; it is better that neighbouring communes, and even private forest owners, should unite to hold large sales, if their own fall of timber is small.

It is evident that most large timber-sales in which only large capitalists can compete, are chiefly sales of standing trees by area; for instance, in West Prussia, sales of 10,000 to 20,000 cubic meters (7,000 to 14,000 loads) of standing wood for three or five years are effected. Sales of 5,000 to 6,000 cubic meters (3,500 to 4,000 loads) of converted timber are not rare; as, for instance, in the forest ranges of Jachenau, Walchensee, &c. of the Bavarian Alps, also in the case of the enormous masses of wood killed in S. Bavaria by the nun-caterpillar, for which sales of 400,000 and 500,000 cubic meters were held. It is not advisable to hold mixed sales of timber and firewood when chiefly wholesale merchants are competing.

Similar principles underlie the formation of sale-lots. The amount of competition and the class of traders present will decide their dimensions. The wishes of the public should also be so far followed in this respect, that it may be possible for large dealers to purchase separately the assortments which their business requires. These consist chiefly of the better class of stem-timber. Where sales are held to satisfy local demands, only small lots are advisable.

Whilst in sales of standing trees, lots may consist of 500 to 1,000 and more cubic meters (350 to 700 loads); in large regular sales of converted wood the lots seldom surpass 30, 50, or at the most, 100 cubic meters (20, 35, or 70 loads): as a rule they are even smaller. It is otherwise in extraordinary falls of large numbers of trees, owing to storms, &c.; in such cases the size of the lots increases with the quantity of material to be disposed of, and the capital of the competing merchants. In the sale of wind-fallen timber in the Vosges mountains, in 1892, besides smaller lots, large lots of 5,000 and 8,000 cubic meters were formed; and in the case of trees killed by the nun-caterpillars in Bavaria, the lots attained 10,000 cubic meters. Whether, in forming the lots, the same care should be taken as in forming the assortments of timber, *i.e.*, that the same lot should only contain the same quality of wood, depends on the numbers and kind of would-be purchasers present. [In the French State forests no lot of standing timber offered for sale should exceed 10,000 fr. (£400) in value.—Tr.]

9. *Conditions of Sale.*

It is self-evident that burdensome conditions, displeasing to the purchasers, will reduce competition, and that the sale will be the more profitable the less stringent are its conditions. On the other hand, the security of the owner against loss, and the demands of sylviculture, must be ensured. It is difficult to say how far a forester can go in the latter direction without prejudice to the interest of the forest owner; it depends on the state of the market and of prices, the solvability of the purchasers, the cost of transport, and the actual demands of sylviculture. The less favourable the local and temporary conditions of the timber-market, the less must one insist on conditions of sale which reduce competition ; and this is more necessary when the purchasers are dealers than when the wood is disposed of among local persons.

One of the most important points is whether cash-payments should prevail, or credit be given. The question is regarded from different points of view in different countries. In most German State forests, except quite recently, cash-payment was the rule, but this has been considerably modified of late. Credit increases the work of accountants, often encourages swindling and indiscretion on the part of certain purchasers, but all this shady side of the credit system disappears compared with the disadvantage of reducing competition by demanding ready money. Credit is now-a-days such a necessary condition of all trade and business, that the forest owner cannot avoid it. Sufficiently long credits, up to a half-year and even longer, in the case of trustworthy large dealers, are conditions which much experience, far from verifying the fears of extensive loss which have been expressed, has proved thoroughly justifiable in the interest of forest owners.*

It is self-evident that credit can be given to doubtful purchasers only on sufficient security (after payment of 25% of the purchase money, deposition of valuable documents, promissory notes on good banking houses, &c.). In the different German States and in Austria, various systems of credit prevail, for instance, in Baden, 3% discount is given for cash payment, otherwise three to eight months' credit.

[In India, deposition of Government promissory notes, on which interest continues to be payable to the depositor, is the best form of security in wood-sales. It can also be stipulated that in sales of standing trees, one-third of the purchase money is payable after the wood is converted, and the balance on removal of the wood from the forest, more than sufficient wood being retained in the forest to cover the balance of the purchase-money.—Tr.]

The date fixed for removal of the wood from the forest or depot is also an important condition of the sale. If the limit allowed is too short, or not fixed with due reference to the cost of transport: if carts and beasts are few and are required for the time being for agricultural purposes, the cost of transport will be increased, and the price of the wood consequently falls. In fixing the date for the removal of the wood, the forester should respect general departmental orders, but in carrying them out he should be very lenient and consider the nature of the roads, that in some cases sand does not bind in winter, or other roads are too wet for use except during frost, or after dry summer weather; that in the case of water-carriage the logs cannot always be floated or rafted at a fixed time, and that country people prefer to work at wood-transport before the hay is mown, or after the corn has been harvested. If all the wood has been brought out of the forest, sylvicultural rules will not intervene to hurry on the removal of the wood from the road-side.

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* The accountant's office at Aschaffenburg, which receives payment for the oakwood from the Spessart, had to receive between 1863—73, £111,400, of which only 27*s.* was a bad debt.

10. *Advertising Sales.*

It has been already remarked, that competition at sales is greatly improved by judicious and timely advertisement. As no petty dealer is afraid of the expense involved in bringing his goods to the notice of consumers, and wholesale producers often spend immense sums in this way with good results; it cannot be doubted that in forestry, judiciously advertising timber-sales must have an important bearing on their financial results. Too great economy in this matter will certainly entail loss.

It should, however, be clearly understood, that no allusion is here intended to puffing advertisements, which are more calculated to excite mistrust than to stimulate purchasers. The advertising medium should be much more carefully chosen than is usually the case. Here is meant, not only advertising in the public press, but also the despatch to large dealers and other persons interested in the sales of printed notices giving sufficient detail of the sale-lots.

Wherever large numbers of logs are sold yearly, and there is a more or less extensive demand for them, the timber-trade may reasonably expect to be informed by notices published beforehand, what woods and felling-areas will be taken in hand, and what will be their probable yield, so that timber-merchants may undertake contracts and make other preparations for the expected timber. In France and in many forest ranges of Prussia, Baden, Bavaria, &c. such notices are now issued regularly.

11. *Means of Transport.*

The great influence which the available means of transport has on wood-prices is well known, and has been already referred to. All unwise economy in providing good means of transport depresses prices, and improvement in this respect should be one of the first objects of the forest owner.

Every intelligent forest owner will endeavour to reduce the cost of transport from his forest. The forester therefore lays-out new roads, improves old ones, regulates floating channels, constructs slides, sledge-roads or tramways; establishes depots on the banks of streams and canals and at railway stations; he will see to the drying and seasoning of his wood, and in certain cases will convert his timber and split his firewood in the forest.

He should not be too narrow-minded in allowing the public use of the forest-roads. If a forest is to be lucrative, its roads should be always open, provided they communicate with the general network of public roads. The higher cost of repairs will be fully recovered by the improved means of transport.

Of immense importance, in this respect, is the proximity of railroads to the forests. Reduction of railway-rates for wood, and introduction of railways into the forests are vital interests to forest owners, which they, in conjunction with the timber-trade, should use every possible means to secure.

[In Britain, this question is complicated by the fact that railway companies grant through rates for timber and other produce from their ports to the large inland towns, which are actually less than rates from intermediate places between the port and the place of destination of the timber. In this way foreign timber is unduly favoured.—Tr.]

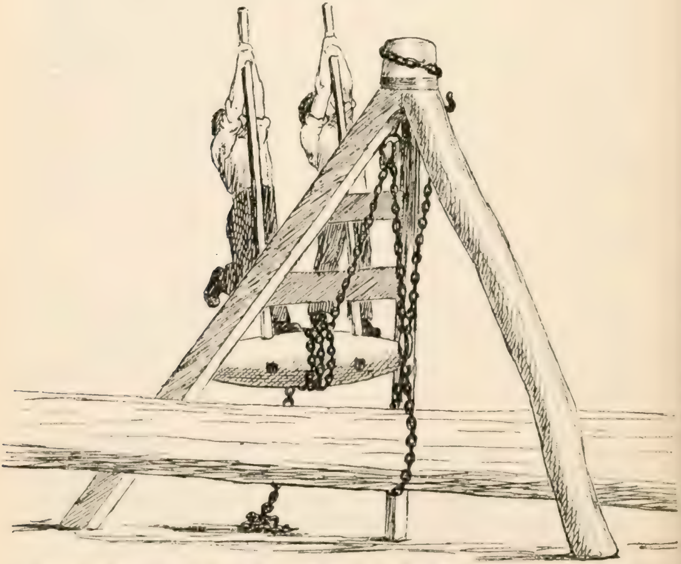
For owners of extensive forests, provided that sylvicultural requirements are not infringed, it is generally justifiable to entrust the transport of forest produce to contractors, as they can generally work more expeditiously and cheaply than large owners, and especially than the State.

12. *Forest Officials.*

If the manager of a forest is expected to work it to its full financial advantage, he must be allowed a free hand in timber-sales, so that he can act without delay in accordance with the demands of the market. Cases constantly arise when owing to an overstocked market the competition at auction-sales of converted timber is too slack, and other modes of sale must be tried.

Although control is necessary, especially in large State departments, yet it should not be too rigid, and a trustworthy executive official should not be too much fettered by routine but left sufficiently to his own responsibility, mere routine in timber-sales having disastrous results to the forest owner. Now-a-days, thousands of pounds may be gained by taking time by the forelock, and using telegraphic communication between buyer and seller.

FIG. 265.



MODE OF RAISING LOGS ON TO CARTS. *Drawn by* T. H. MONTEATH. (*Vide* p. 321.)

PART II.

HARVESTING AND DISPOSING OF MINOR FOREST PRODUCE.

THE term **minor forest produce** comprises all the useful products of a forest, except wood. The very term implies that, as a rule, these products fill only a subordinate roll in forestry, and should be utilized only so far as this can be done without prejudicing the yield of wood, which is the principal forest product. Some articles of minor forest produce (such as forest litter) may be commercially valuable, and at the same time afford important assistance in the production of wood, so that their harvesting may prejudice the latter. Other products (such as grass) are less important in assisting wood-production, while some are thus of no importance at all (stones, for instance), and yet the very existence of certain industries may depend on their utilization. As long, however, as the continuous production of wood is the object of forestry, the industrial importance of any article of minor produce must be less considered the more important it is as a means of wood-production.

As the utilization of articles of minor forest produce has more or less influence on the tending of forests and the production of wood, it has become customary in books on forest utilization to deal with them from every possible point of view. Their partial relations to the subjects of forest protection, forest utilization, sylviculture &c., do not justify us in dealing with them separately under each of those heads.

In the present book, therefore, the usual practice will be followed, and all the more important points regarding the following articles of minor produce will be described :—

I. THE BARK OF TREES.

II. FOREST FODDER.

III. FIELD-CROPS COMBINED WITH FORESTRY.
IV. THE FRUITS OF FOREST TREES.
V. FALLEN DEAD WOOD.
VI. STONES, EARTH, &c.
VII. FOREST LITTER.
VIII. RESIN.
IX. LESS IMPORTANT ITEMS OF MINOR PRODUCE.

[Game and fisheries in forests are generally included among Minor Forest Produce, and frequently yield considerable revenues. In German State and communal forests, the right of shooting deer, hares, &c., is either leased for a term of years, or is exercised by the local forest officials, the game which they shoot being sold and its price credited to the State. The right of catching fish is also leased, especially in trout-streams in hill-forests in Germany. In France the right of hunting red-deer or wild-boars, or of shooting these and smaller game, as well as fishing rights, are leased for a term of years in both State and communal forests. For further details, *vide* Schlich's Manual of Forestry, Vol. IV., also Illustrirtes Forst und Jagd Lexicon, edited by Dr. Fürst, and other special works.—TR.]

CHAPTER I.

UTILIZATION OF THE BARK OF TREES.*

SECTION I.—GENERAL ACCOUNT.

WITH the exception of a few other employments for bark in certain countries, which will be referred to at the close of this chapter, the bark of trees serves principally for tanning. In order that skins of animals may be utilized for boots, articles of saddlery, &c., they must be subjected to a process which preserves them from decay, and renders them more or less supple.

There are four methods at present employed for preparing leather, that termed **tanning**, when substances containing tannin are used for the purpose; **tawing**, by means of aluminium salts; **shamoying**, by means of fats or oils, [and the fourth, by means of compounds of chromium.—TR.].

[Tanning produces ordinary leather; tawing—kid and other white leathers which may be dyed various tints—and shamoying, which is the oldest process, produces wash-leather. The process by means of chromates is a comparatively recent discovery, 1882, and has been reported to produce leather stronger than the best bark-tanned leather.—TR.]

Tanning is effected by the affinity of tannic acid for the albumen and gelatine in skins, the process partaking of a chemical as well as of a physical nature; by the union of these substances a firm but supple compound is produced, which is insoluble in water, resists decay, and penetrates all the other components of a skin, without damaging its natural structure.

In Germany, the production of tanning materials is chiefly limited to the bark of trees. Nearly all indigenous forest trees contain tannic acid in their bark, young shoots, &c., but only a few yield it in sufficient quantities to be commercially utilizable. These few are oaks, spruce, to some extent also larch, willow, and birch. Even chestnut-wood* is now used in Savoy for the production of tannic acid. The oak heads the list both for richness in tannic acid and quantity of production, and oak-bark is at present reputed as the best tanning material in Germany, Belgium, and England.

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* In Prussia, bark is considered an article of principal forest produce.

The tanner considers only young oak-bark suitable for rendering leather water-tight, a faculty more or less wanting in other tanning materials, and which, according to chemists, is owing to the starch in the young bark.

As regards tanning materials from foreign countries, the following list is given :—**Catechu**, an extract rich in tannic acid, from the wood of an Indian tree, *Acacia Catechu*, Willd., and the leaves of a Malayan shrub, *Uncaria Gambia*, Roxb. ; also in small quantities from the nuts of the Indian palm (*Areca Catechu*, L.) ; **Dividivi**, the dried husks † of the pods of a small tree, *Caesalpinia Coriaria*, Willd., which grows in Brazil and the West Indies [and has been introduced into the East Indies.—Tr.] ; **Bahla** consists of the pods of a *Mimosa* ; **Valonea**, of the cups of acorns of *Quercus Ægilops*, which grows chiefly in the Levant and Greek islands, &c., it is a very powerful tanning agent, chiefly used in the tanneries of Southern Europe, and is now being increasingly used in Germany to strengthen weaker tanning substances. A very powerful tanning material is **Quebracho wood** (*Aspidosperma Quebracho*), from the river Plate ; it is cut into shreds, and used with tanning bark ; **Myrobalans**, the fruits of *Terminalia Chebula*, *T. bellerica*, and *T. citrina*, are largely imported into Europe from India.

[Besides the above substances mentioned by Gayer, **Mimosa bark** from various Australian acacias—chiefly (*A. harpophylla*) from Queensland, the black wattle (*A. mollissima*), the gold wattle (*A. Pycnantha*), the Tasmanian silver wattle (*A. leucophylla*) and (*A. cyanophylla*)—is largely imported into the United Kingdom ; and **Hemlock-bark**, the bark of *Abies canadensis*, is the most important tanning material in the United States, its extract being imported into Europe. At Cape Town, the bark of *Acacia saligna*, a naturalised W. Australian species, is the mainstay of the tanneries.—Tr.]

* [There is a factory near Stuttgart in Württemburg, where chestnut-wood is cut into shreds and boiled-down for the purpose. A similar factory at Nancy, in France, uses 2.600 loads of oak-wood annually, the wood being taken from the refuse of fellings in oak-forests, broken branches, stumps, roots, &c. (Boppe, *op. cit.* p. 108.)—Tr.]

† [The seeds contain an oil injurious to leather and must be removed.—Tr.]

Southern Europe, especially the southern provinces of Austria-Hungary, produce certain tanning substances, which are not only locally important, but are exported to other countries; these are **Knoppern-galls, Galls,** and **Sumach. Knoppern-galls** are rough excrescences on acorns of the pedunculate oak, produced by various gall-wasps, chiefly *Cynips calycis*, Burgod. **Galls** are more or less round and smooth growths on the twigs and petioles of several species of oak, caused by *Cynips gallae tinctoriae*, L. Those from southern countries, such as Aleppo, Turkey, and the Levant, are superior to those from Istria on *Quercus Cerris*; Hungarian galls are the worst, and those appearing on the leaves of oaks in Northern Europe have no commercial value.

[Except the knoppern-galls, galls are too valuable to be used for tanning, containing much gallic acid used for ink and dyes.—TR.]

Venetian sumach is a tanning material prepared from the leaves, young twigs, and bark of the wig-tree (*Rhus Cotinus*, L.), which grows abundantly in Transylvania, Hungary, Dalmatia, Venice, South Tyrol, &c., often as coppice, and is cut annually, dried, and ground into tan.* **Sicilian sumach** is similarly prepared from *Rhus Coriaria*, pollards of which are grown in Sicily.

For the quantity of tannic acid in these various substances, special works† should be consulted, the only source of interest here being young oak-bark. The amount of tannic acid this contains varies considerably with the locality, age, mode of growth, &c., and in commercial oak-bark, the extreme limits of the contained tannic acid are 6 and 20 °/₀.‡

From the numerous analyses which have been made of oak-bark from the provinces of South Germany and Austria-Hungary, the best kinds of young bark contain 15—20 °/₀ of tannic acid; middling kinds, 10—15 °/₀; old bark, 8—10 °/₀; in North Germany, oak-bark gives an average of 6½—10 °/₀, and spruce-bark 6—8 °/₀. The tanner, however, does not attach much importance to analyses of bark, but trusts to appearance, taste, and smell. From the researches of Hartig, thin twigs (wood and bark) of young and old oaks in winter, as also unlignified spring shoots, contain as much tannin as the fine bark of oak-coppice.[*]

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* *Rhus Cotinus* also grows in the Himalayas, its wood termed yellow-wood, or false Brazil-wood, is used commercially as a yellow dye.

† [Encyc. Brit. Ninth edition, Vol. XIV. "Leather."—TR.]

‡ The results of numerous analyses of oak-bark, from the Bavarian Palatinate, are given in the reports of experimental stations of the Bavarian Agricultural Society, 1861, Vol. 3. Also Theo. Hartig, Gerbstoff der Eiche, 1869.

SECTION II.—PRODUCTION OF YOUNG OAK-BARK.

Tans prepared from the bark of young oak-trees form the best possible tanning materials. Extensive forest tracts stocked with oak-coppice are required for its production, and both in quantity and quality far outvie the yield of older oak-trees. For that reason, a separate account is given here of the production of tan from young oak-trees, as compared with that produced by old oaks and other species of trees. By young oaks are meant both seedling and coppice growth up to a limit of 25 years.

Before considering the mode of harvesting oak-bark, it will be useful to give a short account of the various conditions which affect its quality.

1. *Conditions affecting the Quality of Bark.*

(a) **Species.**—Oak coppice-woods in Germany are partly stocked with the sessile oak and partly with the pedunculate species. In the best localities for oak-bark, the Odenwald, the Bavarian Palatinate, the Hundsrück, Taunus, the valleys of the Neckar, and hills of the Middle and Upper Rhine-Valley, it is, with very few exceptions, the sessile oak; only in the lower lands, near the water-courses, does the pedunculate oak take its part in these woods. In the North German plain (as in Britain), on the contrary, the pedunculate oak prevails; also in the neighbourhood of the Harz and Siegen, in Silesia and in most oak-bark coppices in Austria. Each of these species yields the largest quantity and best quality of bark in the locality that is best adapted for it. In South and Central Germany, the bark of the sessile oak is preferred; in this region also it is much the easier of the two oaks to peel. The Turkey-oak is used here and there in Austria for the production of bark, but on account of its forming, at an early age, a deeply-cracked *rhitidome*, or dead bark, and because its numerous bundles of bast penetrate the sapwood deeply, and render peeling very difficult, it is of little value.

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[*] 14 cwt. of oak-bark, containing 1 cwt. of tannin, are required to convert into leather 2 cwt. of fresh skins. 2 tons of spruce-bark will produce the same effect. Boppe, *op. cit.* p. 109.

Bark of *Quercus Ilex* contains more tannin than that of deciduous oaks. Boppe, *op. cit.* p. 107.

(b) **Locality.**—It may be stated as a rule proved by experience, that not only the quantity, but also the quality of oak-bark is directly proportional to the energy of the coppice-growth, for quickly grown, vigorous oak-shoots produce most tannic acid. The percentage of tannic acid for oaks of equal age is directly proportional to the thickness of the bast and cortex, and this is known to depend on the greater or less vigour of their growth. The nature of the locality is therefore the most important factor in the yield. If the oak, when compared with many other trees, has a very limited range in which it is at its best, this is even more marked with oak-bark coppice. A mild climate and a loose, sufficiently moist and minerally rich warm soil are essential conditions for this to be remunerative.

The climate is undoubtedly the chief factor in the production of tannin. All tanning materials are the richer in tannic acid, the more southern the country in which they are produced; this is the case with galls and other substances, and is equally true for oak-bark. The mild climate of the Rhine-valley and the adjoining districts, especially the Moselle-valley, Rheingau, the district of the Saar and the Odenwald, affords the best oak-bark coppices in Germany. Oak-bark is also produced commercially in the Silesian hills, Saxony, the North German plain, Brunswick, Mecklenburg, &c., but it cannot compete with Rhenish bark. Many districts in Austria are more favourably situated for successful production of bark, which is there produced in fairly large quantities. Districts where the vine is cultivated in the open, or where at any rate the better classes of fruit trees flourish, may be cited as suitable for a remunerative yield of oak-bark. The richer the soil in suitable mineral matter, the better, provided it is sufficiently porous; for the demands of the oak on heat require a loose soil easily capable of being heated. Wet, even damp places are not suitable for oak-coppice. Most oak-coppices are on southerly aspects of hills, on Bunter sandstone, Grauwacke, Argillaceous schist, porphyry or limestone, or on gravels in the wide river-valleys.*

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* [From the above, it is evident that oak-bark coppice should prove more remunerative in the south of England, Wales, and in Ireland, than in Scotland. —Tr.]

(c) **System of Management.**—All oak-bark woods are managed as coppice, because the quickest growth in youth is attained by coppice-shoots, rather than by seedlings. Besides pure coppice, a mixed system of field-crops and coppice (Ger. *Hackwald*) is also employed. Although much benefit to the production of bark has been ascribed to the cultivation and burning of the soil which accompanies this system, it cannot be admitted that cereal crops are compatible with a rational method of bark production.

Without considering the impoverishment of the soil which must result at each cereal harvest, the disadvantage of the method consists chiefly in the fact that the coppice is in this case kept much more open than is consistent with a large production of bark, that the earth at each felling is withdrawn from the stools in order to supply loose soil for the cereal crop, and that it is washed-down from slopes. Even from financial and national-economic points of view, this mixed system is inferior to simple oak-coppice.

(d) **Rotation.**—The bark should be peeled when the bast is thickest, and before the cortex cracks owing to the formation of rhitidome; from this period the bast, which contains twice as much tannic acid as the rhitidome, will thicken no longer. Such bark in Germany is termed *Spiegel-rinde*, **silver-bark**, and is most highly esteemed by tanners. Soon afterwards rhitidome is formed, and this inferior bark is termed *Rauh-rinde*, or **coarse bark**. In the best districts for oak-bark, where its production is properly regulated, the coppice is felled when from 14 to 20 years old, as then the best bark is obtained. Wherever there is a wish to obtain fairly utilizable wood as well as bark, as for instance, in many municipal and private woods in Franconia, Württemberg, &c., the rotation is fixed at 25, or even 30 years.

The tanner estimates the value of bark by the appearance of a transverse section. If a transverse section of a piece of young bark is inspected, two layers are noticeable, a reddish brown outer layer, the true bark or **rhitidome**, and a light coloured layer, the **cortex** with the **bast**. The thicker the inner whitish or pink young cortex and bast, and the thinner the rhitidome, the more tannic acid a bark contains. That period of its life in which oak-coppice is growing most vigorously, in which its annual shoots are strongest, is necessarily the best for the yield of tannic acid, as then there is the greatest accumulation of reserve-material.

(e) **Mixture with other Species.**—Oak-bark coppice is not always exclusively composed of oak, but beech, hornbeam, birch, hazel, or conifers are more or less represented in the crop. It is especially the hazel, making such heavy demands on the soil, and the broom, which are frequently in excess. It should, however, be a general rule on all areas suitable for oak and where it is intended to grow oak-bark coppice, to maintain as much as possible a crop of pure oak; the net revenue will rise and fall in proportion to the comparative scarcity or abundance of other species besides oak. Neubrand rightly declares that a mixed coppice on a good soil is a sure proof of bad management.

Only on poor soils may a temporary soil-improving mixture of non-exacting species which give little shade be permissible; thus, on deteriorated soil Scotch pine and birch may be planted in order to cover blanks quickly, and the Scotch pine subsequently removed as oaks spring-up under its light shade. Wherever a mixture with conifers appears to be permanently necessary, the locality is not suitable for oak-coppice. The hazel, which is a very exacting species, should never be allowed in an oak-bark coppice.

(f) **Density of Crop.**—Owing to the exacting nature of the oak as regards heat and light, an oak-coppice should not be too densely stocked. If, however, the crop be too open, the quality of the soil will deteriorate, and this must be prevented. When young, the crop should be as dense as possible and kept so until the lower shoots are killed, and the dominating shoots require more room. Then thinnings should be made, so as to reduce the number of shoots gradually to those which are most vigorous, which should be afforded room for full development in accordance with the demands of the oak for light. 1,600 to 1,800 strong clumps per acre form an average crop, and should be kept properly thinned. In planting oak-coppice, a distance apart of more than 5 feet should not be allowed.

Experience in the Odenwald regarding the importance of thinnings on the quantity and quality of the bark produced, fully attests their value. This operation is commenced when the coppice has passed two-thirds of its rotation, species other than oak and badly developed oak-shoots, which grow obliquely away from the clumps instead of vertically upwards, being removed, and only the strongest shoots left. In the Odenwald such thinnings have been in force for 30 years, but they are hardly known in many other places.

(g) **Maintenance of Standards.**—In many woods when the coppice is felled, seedlings or strong coppice-shoots of oak, birch, Scotch pine, larch, hornbeam, &c., are left as standards and kept for a second or third rotation of the underwood with the object of producing inferior timber, as well as bark. There are oak-bark coppices which present the appearance of coppice-with-standards (Franconia and Württemberg, &c.). Independently of the fact that each standard kills the other shoots of the same clump, and when it is felled a blank is caused in the wood, the shade it throws on the surrounding clumps must retard their development. Wherever, therefore, oak-bark coppice is properly grown no standards are allowed.

Schuberg shewed in his observations on the yield of oak-bark coppice, in two coppices in which standards were maintained, that shaded felling-areas yield bark not only inferior in quality but in reduced volume, there being in the latter case a reduction of 30 to 35 °/。. Neubrand wisely remarks that if timber is required, it is better to grow it in high forest rather than impair the quality and volumetric yield of bark.

(h) **Accessory Usages.**—It should be thoroughly understood that it is quite unjustifiable to remove leaf-litter from oak-bark woods, which frequently grow on soil not naturally rich but protected by the shade of the wood, its whole strength being required for the coppice. As a deplorable proof of this statement may be cited the wretched condition of hundreds of acres of coppice belonging to municipalities and private owners. The soil of woods thus maltreated, by depriving it of dead leaves for litter, becomes so rapidly impoverished as hardly to yield half the returns from a similarly situated wood where the litter is preserved. Similarly, pasture and grass-cutting should not be allowed in oak-bark woods, for the trampling of the cattle and the sickle of the grass-cutter have disastrous effects on the stools. In some localities in the middle Rhine-valley leaf-fodder is unfortunately still utilized in oak-bark woods. Even so, when only a moderate use of litter is practised, the bark cracks at an early age, becomes encrusted with lichens, and frequently no silver-bark is obtainable. Broom may perhaps be removed carefully, but it is better to leave it, especially where cereal crops are grown intermediately with oak-bark, as the cereal harvest will be all the richer for the ashes left on the ground when the broom is cut and burned. The Hauberge near Siegen affords a clear proof of the damage done by grazing, the browsing of the cattle there often reducing most markedly the quantity and quality of the bark.

2. *Harvesting the Bark.*

The work of harvesting the bark may be divided into three parts, **preparatory work, peeling** and **drying.**

(a) **Preparatory work.**—As has been already stated, in most oak-bark woods there is a mixture of other species with the oak. Partly in order to obtain more room and time for the business of peeling the bark, partly to avoid deterioration in value of the wood of the mixed species if it is cut during the season of growth, but chiefly in order to expedite the peeling operations, all the mixed wood in an oak-bark coppice is felled at a sufficiently early date so that it may be removed from the felling-area before the peeling commences. This is usually during the winter before the peeling. At the same time, in many places, all oak-wood which cannot be stripped, epicormic branches and shoots growing more or less horizontally along the ground are removed. In the Odenwald, the side-branches are removed from the oak-shoots, as far as the wood-cutter can reach with his bill-hook.

Where cereal crops are also cultivated, as soon as the mixed wood has been felled and the soil is no longer frozen, the first cultivation of the ground around the oak-stools is effected. The sods of grass or heather thus loosened dry better than if the work was only undertaken at the end of the peeling, when the time for sowing is approaching. Wherever there are standards over the underwood, those intended to be felled are marked as soon as the mixed wood has been felled. The felling of these standards, if at all large, will naturally stand over until the oak-coppice has been felled.

(b) **Season for Peeling.**—Oak can be peeled at any time from May till the middle of July, but peeling should be effected as soon as the buds begin to shoot, which, according to locality, is from the end of April till the middle of May,* and at the first appearance of the foliage, the bark is most easily peeled. In extensive woods, as a rule, the work is commenced as soon as the bark is removable after the first flow of sap, and is then conducted as rapidly as possible: firstly, on account of the comparative ease with which peeling can be done early in the season; secondly, so that the young shoots may mature their wood before they become endangered by autumn-frosts, and finally, because it is probable that there is more tannin in the bark in spring than in summer, after much of it has passed into the foliage and young twigs of the coppice.

The state of the weather has considerable influence on the peeling. In damp, calm weather, especially when accompanied by light and warm showers of rain, the bark is most easily peeled early in the morning and late in the afternoon; this is also the case when the soil is moist, rather than when it is dry: in windy, dry or cold weather and at midday during hot weather, peeling is difficult. The sessile oak is always more easily peeled than the pedunculate oak, but the latter may be peeled about ten days earlier than the former. Larger stems are more easily peeled at the commencement of the season, smaller stems at the middle and end of the season. Theodore Hartig states that tannic acid is transformed into sugar soon after the foliage has appeared, this begins in the buds and continues with the leaf development. This fact is evidently in favour of early peeling.

In unfavourable localities, where damage by autumn-frosts is inevitable, the forester is obliged to abandon the whole first year's crop of shoots. The injured shoots are then either cut-back in the following March, making way for a stronger growth which repays the loss of the first year's wood, or the peeled oak-stems are left standing till the succeeding winter, are then felled and the succeeding crop shoots up early in the spring. This custom is followed in some valleys in the western Schwarzwald.

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* In England this is from the third week in April till about the third week of May, in Scotland about a month later. A. D. Webster, Practical Forestry.

[In order to be independent of the natural movement of the sap, H. Maitre, in France, in 1864, adopted with good results, a system of peeling oakwood after steaming it, the wood being removed in billets with their bark to the factory and there steamed in closed retorts, after which the bark is easily removed. This system was improved in 1871, by de Normaison, an engineer, who used for the purpose an apparatus weighing only 5 cwt., which supplies a blast of superheated steam. This is used on the felling-area, and by the help of 3 men and a boy, 15 to 18 stacked cubic meters (10 to 12 loads) can be peeled in a day and yield a ton of bark. A load of wood and 130 gallons of water are used, and the cost is about £2. The advantages of this method are that the wood may be felled in winter when labour is cheap, and that the bark may be removed and stacked in dry sheds instead of being exposed to the weather or the felling-area. Pieces of wood may also thus be utilized which could not otherwise be peeled. The increased cost of carriage of the wood with the bark on has, however, to be considered.* Gayer states that though there is hardly any loss of tannin due to this method, yet that the leather produced by tan from steamed bark is soft and fine and excellent for saddlery, but not so good for the soles of boots. —Tr.]

(c) **Method of Peeling Bark.**—The bark is peeled either after the stems have been felled, half severed or knicked, or from standing stems.

Peeling felled wood is the method which prevails in Germany: it is followed in the Odenwald, Franconia, the Palatinate, Baden, Württemberg and many other districts. The workmen, divided into small parties, commence felling the coppice-shoots, and should be careful to cut them smoothly and close to the ground. All the crop should not at once be felled, but only as much as can immediately be peeled. It is reckoned that a skilful woodcutter can keep two men employed in peeling. It should be a rule, that every evening not a piece of felled wood remains unpeeled; for only from wood which has just been felled can the bark be readily peeled, whilst from poles which have been lying felled for 24 hours, the bark can be removed only by knocking it with a mallet. As soon as a lot of oak coppice-shoots has been felled, freed from tops and side-branches, and the parts to be barked set aside, the operation of peeling is commenced. This is done differently in different countries. In the Odenwald, the Palatinate, Württemberg, &c., the coppice-shoots and all other wood fit to be peeled are cut into round billets of the length customary in the district; the workman then takes each billet and removes the bark, as far as possible, without tearing it. In order to do this, he lays each billet on a stone or log, beats it with the back of a small hatchet along a certain line, so that the bark opens-out and separates from the wood along this line. In case the shoots are to be used in their full length, as stakes, for hurdle-wood, &c., they are supported at one end on a trestle made of forked sticks. In either case, the bark is stripped-off, either in meter-lengths or of the length of the billets. Only when the shoots are smooth and the bark easily removable can beating be dispensed with; the workman then severs the bark in a line along the piece of wood and peels the latter with his hands and with the peeling-iron.

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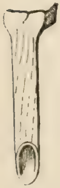
* Boppe, *op. cit.* p. 105.

In Franconia, felled wood is barked differently, being cut into lengths as billets, after being peeled. The shoots having been topped are arranged horizontally on trestles, to facilitate the peeling, and the bark is peeled with an ordinary knife in longitudinal pieces, the full length of the shoots, without being first beaten. These strips of bark are then rolled together into bundles 60 centimeters (2 feet) long and 30 centimeters in girth, and dried.

In the lower Main-valley, the shoots are also peeled before being cut into billets, the bark being removed in pieces of the length of a billet, with the peeling-iron. All shoots over 8 centimeters (3 inches) thick are then sawn into billets, whilst smaller pieces are cut into lengths with a hatchet and their bark beaten with the back of the hatchet. The use of a saw, instead of the hatchet, saves much bark.

The instruments used in peeling bark vary greatly in different districts, but they are of an extremely simple character. The most important instrument is the peeling-scalpel (fig. 266), a piece of wood, or bone, shaped like a chisel at one end, and about 20—30 centimeters (8 inches to 1 foot) long. [In France this is made from the tibia of an ass or horse, with a sharp steel blade attached to its upper extremity.—Tr.] This simple implement is preferable to those made of iron, the best of which are: (fig. 267) a peeling-iron used near the river Saar, (fig. 268) one used near the river Lahn, (fig. 269) Wohmann's peeling-iron. For felling and removing the branches of the shoots, the hatchet (fig. 270) is used in the Odenwald, its back being also used in beating the bark; Wohmann's bill-hook (fig. 271) is also an excellent instrument, especially for peeling bark from standing stems.

Fig. 266.



(After Boppe.)

Fig. 267.

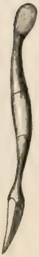


Fig. 268.

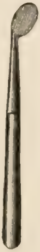


Fig. 269.

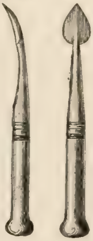


Fig. 270.

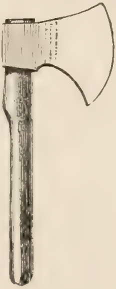
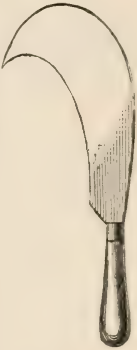


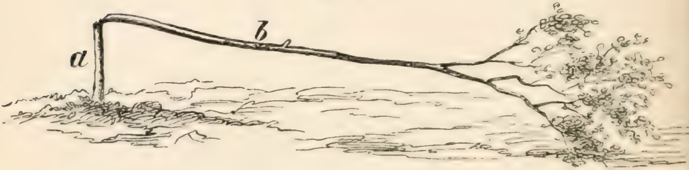
Fig. 271.



The shock owing to the beating loosens the bark from the wood at other points besides those beaten, but the peeling is not always so easy that the bark can be removed in one piece from the wood merely after beating on one side of the pieces; in that case, the billet must be turned and beaten all round, and the peeling-knife brought into play. In every case, however, beating the bark is a rough operation, which always causes a loss of tannin, for the cambium-zone which holds the most tannin is easily crushed, and if rain should fall, much of it is washed away; besides this, the beaten places soon turn brown and become much sooner mildewed than when the bark is not beaten. Considering, that the loss of tannin, owing to beating, has been estimated at about 20%, it is desirable that beating should as much as possible be abandoned, and wherever it is obligatory, that it should be done with wooden mallets, and the shoot which is being barked supported on a broad log or stone, as is done in places along the river Moselle. The smaller and knotty shoots must, however, always be beaten, as well as all the thinner branches, which in the Odenwald are peeled down to 1 centimeter in thickness (·4 inch).

Peeling knicked stems is customary near Burgen, Aschaffenburg and the Hundsrück; it consists, as is shown in fig. 272, in cutting the stem (b) half-through and peeling it, after its base (a) has been peeled standing.

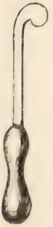
FIG. 272.



A considerable advantage results from this method as only a little beating is necessary. The bark is then usually peeled in long strips, as in the following method.

Peeling standing stems is employed at Lorch on the river Taunus, in some of the Schwarzwald valleys, many oak-bark districts of Austria, and almost universally in France. The branches are lopped from the stem as high as the men can reach, and a strip of bark 2—4 centimeters (about an inch) broad is peeled either with the bill-hook (fig. 271), or the peeling-scalpel (fig. 273). These strips are then rolled into loose bundles and hung from the trees to dry. The rest of the bark is then peeled with a scalpel, without girdling the tree, and is left hanging on the stem to dry. A ladder is generally used in order to peel the upper part of the stem. Thus the bark is not beaten, but that on the branches is not utilized.

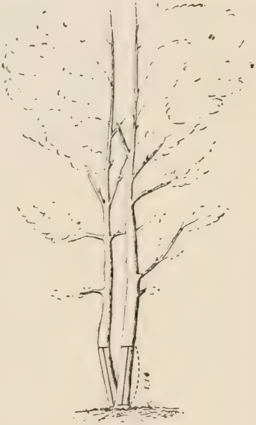
FIG. 273.



In many districts in Austria, all the bark on standing stems is cut longitudinally in strips, and these are then peeled. It would be supposed that in peeling standing stems, the stem should first be girdled close to the ground in order to protect the roots from being peeled. This precaution is, however, often omitted, not without prejudice, as may be imagined, to the reproduction of shoots from the stools.

[It is now customary nearly all over France, in peeling oak-bark, to make a circular cut through the bark of the stem at a suitable height (say 3½ feet) from the ground and a similar one level with the ground (fig. 274); a longitudinal cut is then made between these two marks and the bark removed by means of the bone-scalpel (fig. 266) in a single piece, forming a roll of bark, which can then be dried. Another strip is then removed, as high as a man can reach, and the stem is then felled, and peeled in a similar manner, as it lies on the ground.—Tr.]*

Fig. 274.



(After Boppe).

It is not yet decided whether peeling felled or unfelled stems is preferable, although most foresters prefer the former method; much may be said for and against either. It is contended against peeling standing stems that it is not then possible to use the bark on all branches down to the thickness of a finger, for the upper part of the shoots in this method is frequently left unpeeled.† At the same time, to peel standing stems is advantageous in economising labour, in better drying the bark which remains hanging on the stems, and because beating is then unnecessary. The chief disadvantage of peeling felled stems consists in the fact that beating cannot be avoided; in consequence, the bark depreciates in quality and mildews, the work is more slowly done and there is a considerable loss of bark (about 2¼°/₀) when the axe is used to shorten the billets; whilst by peeling standing stems, the undamaged bark is obtained in a closed roll.

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* Boppe, *op. cit.* p. 103.

† [This is not the case with this method in France.—Tr.]

As regards economy of labour, Neubrand states that workmen at Lorch will peel daily from standing stems $2\frac{1}{4}$—4 hundredweights of bark; by beating, however, with difficulty, $1\frac{1}{2}$ cwt. Neubrand considers beating the worst method, the best being that in force in the forest range of Insbach, near Donnersberg. Here, the lowest part of the bark up to $1\frac{1}{2}$ meters (4 ft. 10 in.) is removed from standing stems, which are then felled level with the ground, but the stumps not completely severed; the top is removed and peeled by beating, whilst the bark from the rest of the stem is removed by the scalpel. Such a method is clearly preferable to felling the whole stem before peeling, for the quality of the bark is not impaired, and the valuable upper bark can be thus utilized as well as in the other method.

(d) **Drying the Bark.**—No part of the business of harvesting bark has such influence on its value as the way it is dried. Any neglect here may cause considerable loss. The less rain falls on the peeled bark, and the more quickly the drying process is conducted, the better. Observations made by Dr. Gantter,* show that rain may deprive the bark of 70 % of its tannin, the relative loss being more considerable with rich bark than with inferior material. If the rain falls at the commencement of the drying process, it is chiefly the tannin which is washed away; later-on, other soluble substances in the bark. Undoubtedly rain is more disastrous on freshly-peeled bark than on bark nearly dried; but the effect also depends on the persistence of the rain. Tanners fear the effects of rain most on dried bark, but probably only on account of its consequent loss in weight. The chief point in this work is, therefore, to effect the drying of the peeled bark in such a way that the almost certain spring-showers may cause it to lose as little tannin as possible, and mildew may not ensue. The best conditions for drying are to isolate the bark from the moisture of the ground, to expose it fully to air currents and protect it from spring-showers. It would have the best effect on the quality of the bark if light sheds were erected in the felling-areas to keep-off the rain. In Hungary, Transylvania, &c., bark is heaped on well-ventilated stages and protected from the rain and dew by large tarpaulins, mats made of reeds, corrugated iron sheets, &c. These coverings are supplied, not only in rainy weather, but regularly every night to keep off the dew. In many places the pieces of bark are piled like a roof, or in a pyramidal shape, being placed, as in fig. 275, against a horizontal pole supported by two forked stakes, the rough bark outside.

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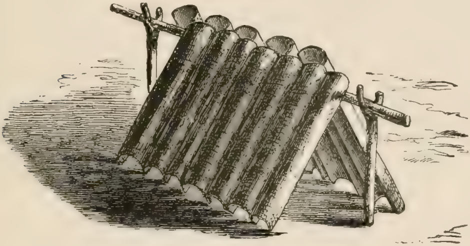
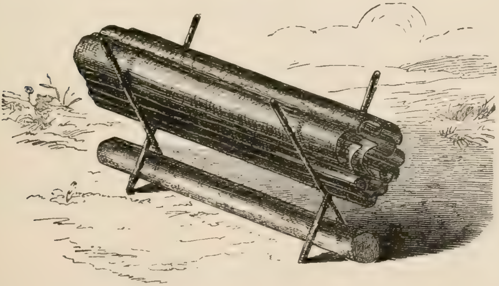
* Handelsblatt für Walderzeugnisse, XV. Year, No. 17.

Fig. 275.



At Lorch, several poles are placed parallel to one another, with one end on the ground and the other on a pole supported by two forked stakes, thus forming a gently sloping stage, usually towards the south, and on this the pieces of bark are placed to dry; or the stages may be horizontal, the poles being supported by pairs of forked stakes, and the bark placed on it. In the Rhine-Valley, drying on trestles is most usual, the bark being

Fig. 276.



supported on stakes driven crosswise into the ground (fig. 276). In this case it is necessary to place the rolls of bark so that they overlap one another, and with the outside uppermost. The looser they are placed, and the fewer pieces there are on a trestle, the quicker they dry. This is undoubtedly a good method of drying bark, as it nowhere touches the ground.

Whenever the bark is allowed to form rolls, the drying process is very simple, for the rolls are generally removed as soon as they are prepared, and left to dry in well-ventilated sheds. If the rolls of bark are not removed till the end of the felling, they should be piled in pyramids of five to ten on the felling-area. The rolls should be loosely tied together so as to admit the air, but the middle of the rolls, enlaced by the withes, frequently becomes mouldy.

When standing stems are peeled, drying the bark does not give any trouble; the strips of bark remain hanging on the trees, and roll-up to such a degree in drying that the inner surface of the bast is thoroughly protected against rain. The loose pieces are hung-up to dry on the top of the stems.

The degree of dryness attained may evidently vary considerably. Practically, however, besides the **green bark**, freshly stripped from the tree, traders distinguish **air-dried** from **meal-dried** bark. Bark is said to be **air-dried** when, on bending, it breaks easily; **meal-dried**, when it has lost all flexibility and becomes brittle. According to Baur, bark, in passing from the green to the air-dried condition, loses considerably in weight; from 32 to 49 %, according to quality, that from the branches losing most weight, and coarser stem-bark the least. The loss in weight, therefore, increases with the age of the wood, *i.e.*, from the foot of a shoot to its top. In a similar way shrinkage of volume takes place, from 21 to 41 %, according to the part from which the bark is taken.

In passing from the air-dried to the meal-dried condition, the bark loses in weight only 4 to 5 %, whilst it shrinks in volume 11 to 20 %. Schuberg found a loss of weight of 35 % for bark passing from the green to the air-dried condition, and a further loss of 14 % in becoming meal-dried.

3. *Assortments of Bark and formation of Sale-Lots.*

In estimating the yield of bark, greater care than is usually bestowed should be given to the business of assorting the bark according to quality; the forest manager should go beyond customary limits of assortment, and have at any rate two classes of silver-bark, for these are the lots which really determine the value of the produce. This is both in the interest of the forest owner and of the purchaser, and will materially decide the results of the sale.

Dry bark is sold differently in different places. Usually larger or smaller bales of it are prepared; or, as in Franconia, it is made into round bundles.

In the Rhine-valley, three sorts of bark are recognized: silver-bark, seconds and coarse bark. **Silver-bark** (*Glanzrinde, Spiegelrinde*) is the bark cut from shoots up to 8 centimeters (3 in.) diameter, in Würtemberg, 12 centimeters (4½ in.), when measured unpeeled; **seconds** (*Raitelrinde*) is from stems 8—25 centimeters (3 to 10 in.) in diameter, in Würtemberg, (4½ to 10 in.), also the smooth bark from the branches of these stems; **coarse bark** (*Grobrinde*) is from branches and stems exceeding 25 centimeters (10 in.) in diameter. Silver-bark is also subdivided into three classes, No. 1, that from the lower part of the stem, No. 2, from its upper part, and No. 3, from branches. The third class is, however, the richest in tannin, sometimes thrice as rich as the 1st class, although traders value them in the inverse order.

The bales of bark are of various dimensions, according to locality. In some of the Rhineland districts large bales weighing 30—35 kilos (say 70 to 80 lbs.) are usual, which can hardly be moved by a man. Tanners prefer the bales to be about one meter long and of the same girth; these dimensions are obligatory in parts of South Germany, and each bale then weighs about 15 kilos (34 lbs.).

As soon as the bark is dry, it is made into bales; this is either done by hand, or in presses. The important points, in either case, are to give the bale its proper dimensions and fasten it so securely that it may withstand the shocks of ordinary transport without opening, or the loss of any bark. Whenever the bark is dried on trestles (fig. 276), the bale is tied as it lies on the trestle. The presses used in the Odenwald are made as follows:—four stout peeled stakes are driven in pairs into the ground at distances somewhat less apart than the proposed length of the bale. Between these pairs of stakes the withes and the bark are laid on the ground. Large rolls of bark are placed first and are piled on either side between the stakes. As many smaller pieces of bark as a man can take in both arms are then placed in the press between the large rolls of bark, until the bale has become about the right size, when large rolls of bark are placed on the top and the bale is then fastened by means of withes, iron wire, or Manilla hemp. The whole exterior of the bale then consists of the larger rolls of bark, the smaller pieces being inside. The fastenings should not be too tight, or the bark may crack and break into pieces, and the bale become loose; this is important, considering the distance to which bark is sometimes transported. The large external rolls will, however, generally stand fairly tight fastening.

The peeled wood is stacked in the usual manner.

4. *Sale of Bark.*

No forest produce is sold so variably as tanning-bark. Taking into consideration whether the sale is chiefly left to the purchaser, or conducted by the forest owner; the chief kinds of sale are:—of the coppice, by **area** or **unit of produce**; and of the converted material by **weight** or **volume.** As regards the public or private nature of the sale, sale to the highest bidder is the rule; but although to the apparent prejudice of the forest owner, sales by private contract are not unusual, often before the market-prices of the previous year's bark are known.

(a) **Sale by Area.**—The mature coppice is subdivided into larger or smaller lots, and each lot, both wood and bark [or these separately.—Tr.], is sold to the highest bidder. The purchaser of a lot converts both wood and bark at his own risk, subject to certain sylvicultural conditions imposed on him at the sale, and endeavours to dispose of the produce to the best advantage.

As by this method it is impossible to form any correct estimate of the value of the crop, it should be absolutely abandoned. At

Hirschhorn, a sale-condition is enforced on the purchaser of the lots of coppice, that he should sell the bark at a fixed price per cwt. to the tanners.

Similarly, some sales are conducted which provide that the forest owner shall have the converted wood and the purchaser the bark, after the latter has converted both the bark and the wood at his own cost. This is one of the most usual modes of sale and is very convenient, though not always most profitable for the forest owner: for, although the felling and conversion is effected under the supervision of the forest staff, and the purchaser's workmen must submit to sylvicultural rules, yet they study the interest of the purchaser rather than that of the owner. Good supervision may, however, remedy matters in this respect.

(b) **Sale by Unit of Produce.**—In this mode of sale also, the price of the bark is arranged before it is harvested, but the felling and peeling is undertaken and paid-for by the forest owner. This mode of sale is far preferable to those described under (a), and is generally the best to adopt; the workmen are then engaged by the forest owner and will see to his interests, and the conversion of the wood will be more profitably arranged as firewood, or timber for agricultural purposes, according to the requirements of the case. There is here nothing to interfere with the best possible harvesting of the bark, and the maintenance of its quality; for if the workmen are paid by piecework, according to the weight and quality of the bark, their interest in the matter will be thoroughly enlisted.

This mode of sale has recently been adopted in several places in Baden, Würtemberg and the Palatinate and in parts of Prussia.

(c) **Sale of Converted Material.**—Another possible mode of sale is when the forest owner converts both wood and bark at his own expense and sells the produce afterwards. This method is seldom adopted and is mentioned here only in order to show how necessary it is to arrange for a purchaser of the bark before the felling. If, however, forest owners were to provide large sheds for drying and keeping the bark, the trade would greatly benefit, and this would lead to the whole bark harvest being conducted by the forest owners.

5. *Measures for Bark.*

In selling bark-coppice by area, it is important to know how to estimate the quantity of bark which has been harvested. This may be done by measuring its **rough volume**; by **weight**; or indirectly, by measuring the **volume of the barked wood**, from which the yield of bark may be determined by means of experimental ratios.

Measurement by rough volume is done by the bale. Although this method has the advantage, that the bark can be removed as soon as it is sufficiently dry, and there is thus little danger of any loss of tannin, yet it affords for both purchaser and seller such an uncertain measure of the yield, that it is employed only to a limited extent. If measurements are to be made by bales, not only must the length and girth of the bales be nearly uniform, but the bark must also be uniformly packed in each bale.

The best, and at present, the most usual sale-measurement is the **weight**. As soon as the bark is dry, it is packed in bales and weighed in the forest by means of a steel-yard or spring-balance. Everything then depends on the degree of dryness of the bark, for green bark must lose 40—50% of water to become air-dried. In the interest of the purchaser, however, the bark must not be kept a day longer in the forest than is necessary, owing to the danger of a loss of tannin. Although one might anticipate disputes between seller and purchaser as to the proper date for measuring bark, yet experience proves that this seldom happens. A prudent tanner will allow the bark to remain in the forest no longer than is absolutely necessary; he knows that it is more to his interest to pay for the bark when somewhat moist than to risk its being badly washed by the rain.

The third mode of measuring bark consists in merely **measuring the peeled wood**, and assuming that its volume will bear a fixed ratio to that of the bark which has been harvested. This custom is always followed in Franconia. It cannot be denied that this method has certain advantages, as it saves labour and avoids inconvenience, but to it is attached the great disadvantage that the ratio between wood and bark varies every season, and neither purchaser nor seller can be certain how much bark has been bought or sold. It may be suggested that an average yield being maintained, matters will adjust themselves in a few years' time; but on the whole, the forest owner will lose, for as long as a purchaser is uncertain of the amount of bark he will obtain, he will generally bid below its proper value. This is, therefore, the most rough and ready of all measurements.

According to Baur, the average ratio of the bark in cwts. to the peeled wood is as follows:—One stacked cubic meter (35 stacked cubic feet) of peeled wood will yield

Silver-bark	0·91 cwt.
Seconds	1·69 ,,
16 years old stem bark	1·45 ,,
25 years old stem bark	1·95 ,,

SECTION III.—UTILIZATION OF THE BARK OF OLD OAKS AND OTHER TREES.

As the tanner will pay only a very moderate price for the bark from young oak-trees, he cannot easily be induced to utilize the inner bark of old oaks or other trees; considering that their cortex and bast are generally poorer* in tannin than that of oak coppice-shoots, and that tan prepared from old bark always contains a certain quantity of the worthless external rhitidome, whatever care is taken to exclude it.

1. *Harvesting the Bark of Old Oaks.*

As in the case of poles, so in that of older trees, the bark is peeled in the spring at the opening of the buds, or at Midsummer, when the second oak-shoots appear. Utilizing the bark of old oak trees, however, involves several causes which are harmful to the forest owner, for felling large oak trees in the spring impairs the quality of their timber, and many heavy stems would thus fall on ground already stocked with young growth. If, therefore, in order to utilize the bark, the forester neglects the improved quality of his wood obtained by winter felling, he should, at least, exclude areas of young growth, which are most liable to damage. Even then, thinnings, preparatory fellings, extraction of old trees from younger woods and seeding-fellings in high forest will still yield much bark for use if required.

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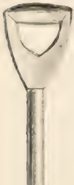
* The cortex and bast of oaks, 40—50 years old, according to Wolff, is as rich in tannic acid as that of oak-coppice, provided all corky substance is excluded.

In some districts in Hesse and Hanover, old oaks are peeled standing in the spring, left standing till winter and then felled. This method [also employed in the Forest of Dean.—Tr.] gives superior timber to that felled in the spring. As a rule, bark is peeled from old oak trees after they are felled, and here also only as many trees should be felled as can be peeled during the day. The men engaged in peeling, who are usually employed by tanners, or merchants, follow close on the woodcutters.

Fig. 277.



The workman makes a cut down the stem and through the bark with the barking-iron (Fig. 277). The bark is then peeled in large flat pieces by means of the iron and the workman's hands. It can seldom be removed without constant beating. Wherever the bark is sold stacked, the pieces are then cut to the required length (say one meter). The less common method of barking standing trees is easier to effect, although ladders are required.

The most troublesome part of the work is to peel the crooked knotty branches which must always be beaten. Sometimes, instead of the barking-iron, the common felling-axe alone is used. If the weather is favourable an experienced workman will peel 4 or 5 large oak trees in a day. Trimming the bark, however expensive it may be, greatly increases its value. The more thoroughly the cracked and dead outer bark or rhitidome, which in old trees forms 50 to 60% of the bark, is removed from the inner and more sappy bark, the more valuable will be the produce; the percentage of tannic acid in old bark would not be so low as compared with young bark, were all the hard outer bark removed. Wherever trimming is done it should always precede peeling, and is best effected on standing trees.

The peeled bark is then carried to a neighbouring blank to be dried. For this purpose it is usually placed horizontally on a stage made of poles, with the cambium side downwards to protect it against rain. As soon as it is dry it is piled between stakes like firewood, being well trodden down in the stacks. If, as is usually and most conveniently the case, the bark is sold in stacks, they should be made by an employee of the forest owner ; in Würtemberg, bark is packed in bales for transport. The bark may also be sold at so much a tree.

A stacked cubic meter of old oak-bark weighs 130—200 kilos (4 to 6 cwt. per load of 50 cubic feet) and more, according to the amount of moisture it contains. More fresh bark goes to a stack than dry bark, for it is easier and softer to pack in the former case.

Sale by the amount of peeled wood is more uncertain than in the case of young bark, owing to great variability in the proportion of bark to peeled wood ; for according to the age of the trees the wood may be proportional to the bark in any ratio from 3 to 1, up to 6 to 1, or even 8 to 1 in the case of very large trees, *i.e.*, there are 3, 6 or 8 cords of wood to 1 cord of bark. (In the case of oak-trees 55 to 62 years old, Baur found this ratio about 4 to 1.) In old oak trees the quantity of bark is greater in the crown, which contains 2, 4 and 6 % more bark than the stem for the same volume of wood ; this is due to the larger surface of the branches than the stems.

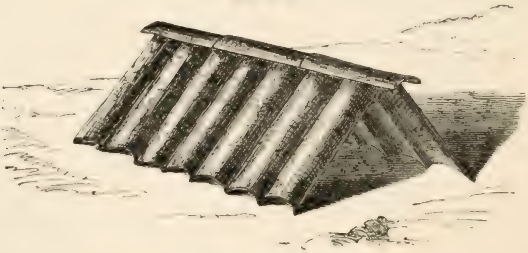
As regards utilization of the much more valuable bark from the branches of old oak trees, von Frivolin has made numerous experiments, showing that there is a gain of 25 to 30 % in utilizing the bark, compared with the mere use of the unpeeled wood for fuel. The oaks in question were lopped of all their branches in the spring, and the stem felled in the succeeding winter.

2. *Spruce-Bark.*

Spruce-bark is much more extensively harvested than old oak-bark, and in eastern and southern Germany and the adjoining Austrian districts when mixed with Knoppern galls, valonea and silver-bark, it is largely used for tanning. It can, however, be used only in the preliminary stages of tanning, or for tanning thin skins ; thick skins are only tanned with spruce-bark when largely mixed with other tanning materials. As most spruce forests are in mountainous regions, where on account of the climate summer-felling prevails, and the wood must be peeled, owing to the danger of insect-attacks, and the necessities of transport, most of the difficulties which occur in utilizing oak-bark are avoided.

In order to obtain spruce-bark, the felled stems after being cut into saw-mill butts, are peeled with the barking-iron or the axe, so as, if possible, whenever the log is not too thick, to remove the bark in one piece. The men, however, prefer peeling the firewood blocks a meter long, to heavy logs and butts. The bark is then spread-out on poles or placed on an incline to dry, or arranged as in Fig. 278, the roof-like structure thus formed being covered with numerous other pieces of bark, and thus secured against the rain. In setting-out the pieces of bark to dry, they are bent outwards so as almost to break along their middle line in order to prevent them from rolling-up, otherwise they would not dry thoroughly.

FIG. 278.



As in all trees, the bark of young spruce contains more tannic acid than that from old trees; and the bark of trees grown wide apart, or in the open, and of trees exposed to the south or along the borders of a forest, is richer in tannic acid than those under opposite conditions.

In most countries dried spruce-bark is stacked like ordinary firewood and sold by the stack; a stacked cubic meter (35 cubic feet) contains 0·3 cubic meters (10 cubic feet) of solid bark. Well-stacked smooth middle-aged spruce-bark, when air-dried weighs from 150—175 kilos per stacked cubic meter (4½ to 5 cwt.

per load of 50 cubic feet). It is also sold by the tree, by the hundred rolls, by the volume of the barked wood, or by the drying stack (Fig. 277) containing 12 to 15 pieces of bark. Selling by the amount of peeled wood is the simplest method, provided sufficiently accurate ratios between the wood and bark have been ascertained; for wood 80—100 years old, this ratio is as 1 to 8—12, averaging 1 to 10. In younger wood the ratio is more in favour of the bark.

3. *Birch- and Alder- Bark.*

Birch-bark is more in use for tanning in the north of Europe, especially in Russia; in Germany it has hitherto been used only experimentally. It contains much less tannic acid than oak-bark, and even than that of spruce, but sometimes repays harvesting when the price of silver-bark is high. In Germany it is not used for tanning, but for macerating sole-leather with the object of opening the pores of the leather and preparing it to receive tannin. Leather tanned with birch-bark is softer and less water-tight than that tanned with oak-bark, but it has a lighter colour and a better appearance.

Birch-bark is harvested in the same way as oak-bark, it can be peeled only about a fortnight later than the latter although the birch shoots first. It is easier to peel old birch trees than young ones, but they are not nearly so easy to bark as oaks. The few data regarding birch-bark give 65—80 kilos of air-dried bark for a stacked cubic meter of peeled birch billets from trees 20 years old (say 2 cwt. per load of 50 cubic feet). Alder-bark is occasionally used for tanning, but is of no more importance than that of birch. Russian leather is tanned with willow-bark, but its pleasant odour is the result of soaking it during the tanning process with birch-oil, which is distilled from the external white layer of birch-bark.

4. *Larch-Bark.*

Larch-bark is seldom harvested in Germany, but is extensively used in Russia, Hungary, and Austria for tanning. According to Wessely, in the Carpathian Mountains and the

Alps it is preferred to spruce- and birch-bark. It is probably unsuitable for tanning sole-leather, but deserves consideration as a substitute for oak-bark in tanning calf-skin. Owing to the straightness and freedom from branches of the larch, it is more easily barked than oak. It is better to bark it in summer than in spring, as the maximum amount of tannic acid is then attained.

5. *Willow-Bark.*

Willow-bark contains a considerable amount of tannic acid. Besides *Salix caprea* and *S. alba*, the so-called osier-willows are best in this respect. According to data furnished by the Moscow Academy, the quantity of tannic acid in willows varies between 8 and 12 %. In Russia, it has for a long time been usual to use willow-bark for tanning, especially in preparing that flexible, water-tight, shining upper leather, for which Russia is so famous. The well-known Danish glove-leather is also tanned with willow-bark. In Germany, little use has hitherto been made of willow-bark, probably on account of the small quantity grown.

Peelings from osiers are dried in loose heaps and used for tanning, or as litter for cattle.

SECTION IV.—YIELD IN PRODUCE AND REVENUE OF OAK COPPICES.

1. *Yield in Produce.*

If oak-coppice is managed for the production of valuable bark, bark must be the principal item in the produce, and the yield in wood can be considered only as of secondary importance. A sensible management of bark-coppice will, therefore, endeavour to secure all the conditions which have been already stated as essential for the production of a large crop of good bark. Besides the cultural conditions, however, the yield of bark is chiefly influenced by the quality of the locality, and it can be readily understood that owing to the great variability of locality and cultural treatment in the case of bark-coppices, that their yield also varies considerably. As an average yield of the best

German bark-coppice districts, with rotations of 15 to 18 years, 60—70 cwt. of bark, and 40—50 stacked cubic meters of wood per hectare, may be cited (24—28 cwt. of bark, and 560 to 700 stacked cubic feet of wood per acre). The longer the rotation, the larger the proportion of wood as compared with bark.

Careful management has an immense influence on the yield. R. Hess has shown to what an extent this is possible, in his account of the management of the forest range Oberrosbach, near Friedberg, which shows, taking one compartment as an instance, that in sixty years the yield was increased 105 % by careful management.

The following examples of the yield of bark-coppices per acre are taken from pure oak-coppices of best quality, and under first-rate management :—

Frauenwald compartment 15 of forest range Oberrosbach, 15 years' rotation :
50 cwt. bark.
670 stacked cubic feet of wood.

Thinned forest (*Hackwald*), forest range Beerfelden, 17 years' rotation :
40 cwt. bark.
1,480 stacked cubic feet of wood.

Forest range Brichold, in Franconia, rotation 20 years :
43 cwt. bark.
1,030 stacked cubic feet of wood.

2. *Revenue from Bark-Coppice.*

The amount of revenue obtained from bark-coppice depends chiefly on the price of bark, for the value of the peeled wood remains pretty constant in most oak-coppice districts.

Baur has shown that peeled wood takes up 17—30 % less volume when stacked than unbarked wood. These figures, therefore, represent the loss in volume in firewood due to the barking, but the loss is compensated for by a rise in price owing to the larger volume of wood in the firewood stacks, and its consequent superior combustibility. It is, therefore, even when the price of bark is low, more profitable to sell the bark for tanning than as fuel with the wood.

Under the various factors which regulate the price of bark, its quality, the demand for it, and the mode of sale, are the most important.

(a) **Quality of Bark.**—The conditions affecting the quality of bark have been already discussed. As the revenue from bark-coppice depends almost entirely on the price of bark, and the latter chiefly on its quality, it is evidently necessary to subordinate the culture of the wood to that of the bark. [In the Ardennes the wood is as valuable as the bark, being used for mine-props.—Tr.]

Whenever the proper rotation is exceeded, many standards preserved, much admixture of other species tolerated, careful cultivation neglected, thinnings omitted, and the bark negligently dried, one need not wonder at lower prices for bark being obtained than where it is carefully cultivated.

(b) **Demand for Bark.**—Next to its quality, the demand for bark is the most important factor in its price. Owing to the constantly increasing demand for tanning material, one might imagine that the demand for oak-bark is everywhere favourable; experience in most bark districts is opposed to this idea, and whilst the tanner is complaining of insufficient production of tan, the forest owner complains of low prices. At present **the prices of tan are low** everywhere. This is probably due to the large import of tanning material and of leather.

The production of tan in Germany is quite insufficient to satisfy the home demands of the tanning trade, which has been estimated at 7,000,000 cwt. of bark, for the production of which 3,750,000 acres of bark-coppice would be required; for in spite of the large imports of leather, chiefly from America, tanning materials to the extent of 3½ million cwt. have been imported recently, although the duties have been raised. France governs the trade in tan over Switzerland and West and South Germany, while Austria supplies the North. The desire of the German tanner for an extension of bark-coppice is therefore justifiable, although the forest owner cannot be induced to follow suit, owing to the low prices.

[The annual production of oak-bark in Britain may be estimated at 250,000 tons and about 16,000 tons are imported annually. This is quite inadequate for the tanning industry, as may be seen from the following figures taken from the official returns for 1894:—

Imports (British and Irish).		
	Tons.	Value.
Tanner's bark	15,994	£124,356
Cutch and Gambier	17,303	254,954
Valonia	24,508	311,119
Raw hides	31,220	1,341,392
Leather	101,696	7,094,156
Exports.		
Leather (excluding boots and shoes)		1,510,828
Skins and furs		985,502

Re-exports of Cutch and Gambier and of raw hides have been deducted from the gross returns of imports.—Tr.]

(c) **Mode of Sale.**—It has already been shown that tanning-bark should generally be sold by auction before peeling the coppice, but that sale by private contract is also sometimes advisable. Sales by private contract, however, should not be conducted in ignorance of the proper price of bark, and should be avoided, unless there are large quantities of bark for sale. In no case should small sales of bark be held; large sales are better attended, when several neighbouring forest owners unite to sell their bark. Such large sales of bark are held at Heilbronn, Erbach, Hirchhorn on the Neckar, Bingen, Kreuznach, Kaiserslautern, and Rüdesheim, the State and neighbouring private forest owners and communes combining to sell their produce. Samples of bark are produced at these sales, which in the Rhine valley, &c., consist of a piece of wood 7 to 8 inches long, cut 3 feet above the ground from a coppice-shoot, and unbarked. Each sample bears a label, on which the name of the owner, the forest, age of the coppice, aspect, altitude, soil, and quality of the bark is stated. The results of the sale are published annually. Up to the present time, unfortunately, only a small part of the bark produced is thus sold. Many communes and private owners abstain from these sales from short-sighted motives, to the prejudice of their own interests.

Wherever the climate and soil are undoubtedly favourable to bark-coppice, and the best attention is paid to produce bark of high quality, the maintenance of oak-coppice is justifiable, and will pay its way in spite of bad prices. Wherever the management is indifferent, half the crop mere firewood, the rotation up to 30 or 35 years, the felling-areas shaded by numerous standards, no tending afforded, the bark-coppice expected to yield plenty of wood and even litter, the preparation of the bark defective, &c., it cannot be wondered that the forest owner is disappointed in his revenues; he had then better turn his attention to hop-poles or wood for paper-pulp, rather than to bark. In such cases, one need not be surprised that the tanner will offer only a low price, since it is always possible for him to use some imported material as a substitute for oak-bark.

In the middle of the present century the question was raised, owing to the outcry of the tanners, whether the increasing demands for bark should be met by converting certain areas of the State high forests into bark-coppice. The German Forest Departments have almost unanimously resisted this demand, and quite rightly, as is now recognized. Independently of the fact that it is not statesmanlike to favour only a single industry, it is evidently the duty of the State to manage its forests so as to satisfy most fully all market demands, and render them in every way most productive. Had the State forests been transformed into coppice as was then suggested, they would now, with the low prices of bark, be in a wretched financial condition.

The cultivation of bark must be left chiefly to communes and private forest owners, especially as they are the principal owners of the localities where bark flourishes.

In thus recommending the cultivation of bark in communal and private forests, not only those areas already under forest are referred to, but those numerous half-cultivated lands bordering on forests, which owing to their position, remoteness, or inferior soil are unsuitable for agriculture, and often afford merely a poor pasturage, but owing to the climate of the locality are in many cases admirably adapted for the production of bark.

It appears as if the strenuous endeavours to manufacture tannin have already proceeded beyond the experimental stage. The initiative taken at Lyons and Nantes has been followed by the establishment of large factories in France Austria, and

Slavonia, which prepare from old oak-bark and refuse oakwood of all descriptions a concentrated extract of tannin which is sold at 40 francs per 100 kilos (16*s*. a cwt.). It is not yet decided as to the importance which may result from the application of certain minerals to tanning.

Pyrofuchsin prepared from wood-tar and coal-tar is also said to be an important tanning agent.

SECTION V.—OTHER USES OF BARK BESIDES TAN.

Regarding other uses of bark, birch-bark deserves a short notice. It is used in Norway and other parts of northern Europe for many purposes. For instance roofing, the underlying plank roof being covered with pieces of birch-bark measuring a square foot, which are placed like tiles and covered with a slight layer of earth. Such roofs last for 50 or 60 years. Birch-bark is also made into vessels of all kinds, which in Norway are even used for salting herrings. The great value of birch-bark to the Norwegians may be imagined from the fact that besides numerous other articles, they make shoes from it. Birch-bark is similarly used on a large scale in Russia. The use of birch-oil in the manufacture of Russia leather has been already referred to (p. 509).

[Canadian birch-bark is largely used for making canoes, which are sewn-together by means of thin spruce-roots. It is also used for packing material. In the Himalayas, the bark of *Betula Bhojpatra* is used for making hats and umbrellas, also packing material, and has been used as paper.—TR.]

The bark of many willows is used in the preparation of salicin, or of lacker-dye, and for cattle-fodder, as will be seen further on.

CHAPTER II.

UTILIZATION OF FOREST FODDER.

THE natural fodder produced by forests is composed of grasses and other herbage growing on the ground, as well as the leaves and young shoots of woody plants. This material can be used in several ways for cattle-fodder, either by driving the beasts into the forest to graze, or by allowing men to cut grass or the leaves of woody plants, and use them for stall-fodder. The present chapter is therefore divided into 3 sections: **pasture, grass-cutting** and **leaf-fodder.**

SECTION I.—PASTURE.

1. *General Account.*

Forest Pasture means the utilization of the herbage and grass of a forest by the admission of cattle. In earlier times, and until the second half of the eighteenth century, this was almost the sole mode of feeding cattle employed in all the forest districts of Germany. In many places forest pasture was exercised without any restriction; it first, however, came into collision with the interests of sport, and later on, care for the forest intervened, and as soon as the development of agriculture necessitated stall-feeding, the first move was made towards withdrawing cattle from forests. If stall-feeding has not yet become universal, and owing to the increased population of the higher mountain-ranges, a steady demand for forest pasture still prevails, there is no comparison between its present condition and that of earlier times. In plains, hilly districts and many low mountain ranges, forest pasture completely loses the injurious importance formerly attached to it, provided it is kept within sylvicultural limits, the enforcement of which is not prevented by any legal rights. In the Alps, however, and some other mountainous districts, forest pasture is still as bad an impediment to forestry as ever.

From a National-Economic Point of View.—The gain to agriculture through forest pasture from the large quantities of grass and other herbage which forests annually produce, and from the maintenance and exercise of the beasts in the open air, is too self-evident to be controverted. On the other hand, the loss of manure is thus largely increased, and whenever, as now almost everywhere, the latter is the turning-point of agricultural profit, forest pasture is clearly a hindrance to agricultural success. Stall-feeding, however, demands increased supplies of fodder, and this in its turn, grass-meadows or rich soils suitable for clover and other fodder-crops. In fertile districts, and wherever rich meadows or other means allow cattle to be fed in stalls or fields throughout the year and they are chiefly kept for the production of manure, the farmer will not think of sending his cattle into the forests to graze. The more unfavourable, however, the agricultural conditions, and the more the farmer is compelled to use all available means in order to be able to feed his cattle at least through the winter, the greater value does he attach to forest pasture. Forest pasture, therefore, at present prevails in mountain-forest regions where the climate is severe, and also in districts where landed property is much sub-divided.

Mountainous districts permit only of poor farming; there, crops of artificial fodder are scanty and the yield in straw is insufficient for the winter's fodder-supply. Most mountainous forest districts are in this plight. The less favourable the conditions for agriculture, the more are the people driven to cattle-breeding, and the more they value forest pasture ; in the Alps and higher mountain-chains of the interior of Germany, cattle-breeding and the production of milk and cheese are the chief popular industries, and forest pasture far exceeds sylvicultural limits. The majority of so-called Alpine regulations allow the villagers bordering on forests to drive as many head of cattle into the State or other forests as they can maintain during winter on their farms ; to leave the cattle day and night in the forests without herdsmen, and to choose their own grazing grounds. Owing to legal decisions there are many local variations and more or less clearly worded modifications in these regulations. Whenever pasture is allowed owing to prescriptive rights, as throughout the Alps, forests are always in a very poor condition, for national-economic reasons will not allow of such a limitation of the rights as to render them harmless. The danger to the forest increases inversely with the area closed to grazing and the necessity for feeding the cattle on areas poorly stocked with grass. In such districts therefore it is in the interest of forestry to favour the production of fodder as much as possible, by not planting grassy blanks, leaving good pasturage open and managing forests under the group system.

In many of the interior mountain-ranges also, for instance the Bavarian forest, pasture is a heavy clog to forestry, even though the herdsmen are bound, before twilight begins, to drive the cattle to their quarters for the night.

Excessive sub-division of landed property is also a great incentive to forest pasture. Where the poor peasant hardly possesses enough land to grow potatoes for his family, and can scarcely manage to stack sufficient fodder for the winter supply of his cattle, he will pasture them as long as possible in the forest. Whenever in a densely populated district which may not be very favourable for agriculture, all the more fertile lands belong to large owners and richer people, the worse lands are so sub-divided amongst the poor that a single plot of land cannot maintain a cow ; a goat is kept instead, and herds of goats, so greedy for woody plants, are added to the herds of cattle.

2. *Production of Fodder in Forests.*

As already stated, forest fodder consists of the grass, herbage, foliage and shoots of woody plants growing in the forest. It is clear that in properly regulated pasturage woody plants should not be utilized for fodder, as then wood could not be produced. At the same time, there are certain beasts which prefer them to other fodder, and there are circumstances, seasons and local conditions when woody plants are dangerously exposed by pasture.

(a) Amount of Forest Fodder.

The amount of grass and herbage produced in a forest depends chiefly on the **fertility of the soil**, the **amount of light** afforded and **climatic conditions**. The richer and moister the soil, the more it is exposed to light and the milder the climate, the more fodder will be produced.

i. *Soil.*

As regards soil, the amount of clay it contains (up to a certain point) is the chief factor in producing fodder; sandy soils produce as a rule the least grass; limestone mountains also produce little grass, being often characterized by scarcity of springs and a slow disintegration of the rock, they also abound in deep gorges. As soon, however, as a little clay is mixed with either sand or limestone, provided that the soil does not thereby become too stiff, or impermeable by water, plenty of grass will be produced. An abundant and constant supply of water during summer is almost more important than a mixture of clay, for grass production. On this account, the crop of grass on a naturally dry soil is markedly increased by an admixture of humus, or by the shelter of a thinly stocked wood [of larch, for instance.—Tr.], which moderates radiation from the ground and protects it from drying winds: for this reason, mountain-forest grazing-grounds and grassy blanks are so much moister than those outside the forest. Anyone can observe the increased deposition of dew in open land with scattered shrubs and bushes which keep-off the wind, and the comparative dryness of similar land without this protection. The depreciation of Alpine meadows in the Tyrol and many parts of Switzerland and Austria-Hungary is chiefly due to the clearance of forests. If the soil once suffers a diminution of steady moisture; moss, sour grasses, rushes, &c. take the place of sweet meadow-grasses. Areas which have been rapidly cleared or swept by storms, with rich moist soil especially on southern aspects, often afford the worst pasturage. They become overgrown with a dense crop of weeds, which leave no room for nourishing grasses. Cattle-grazing in such places almost entirely prevents the growth of all forest trees.

ii. *Amount of Light.*

Grasses, clovers and most fodder-plants are decided light-demanders: on a soil covered with a dense growth of woody plants, or from which light is otherwise excluded, no grass usually grows; only when the leaf-canopy of a wood becomes elevated and admits lateral light, and more and more light reaches the ground under an old wood, does the surface become gradually overgrown with herbage. If the wood is under natural regeneration, and the soil contains some humus and is naturally moist, the production of grass is at a maximum, and frequently struggles with the woody plants for possession of the ground. If the soil be sufficiently fertile, more or less woody plants and shrubs spring up, such as raspberry, blackberry, briars, loose-strife, thistles, hypericums, belladonnas, &c., birch, aspens, sallows appearing here and there; then the woody species which the forest is intended to produce sooner or later disentangle themselves from this heterogeneous vegetation, the grass begins gradually to thin out under their shade and finally disappears when the woody crop is reconstituted.

Light-demanding trees evidently favour the production of grass much more than shade-bearing trees. Among them, oak forests in the broad alluvial valleys and larch-woods* in the mountains are the regular grass-producing forests. Among shade-bearing trees, spruce and silver-fir forests produce more grass than beech-woods, on account of the greater degree of moisture in the former and because their soil-covering of dead needles and moss impedes the germination and growth of grasses less than the dense covering of dead leaves of the latter.

The most grassy places in forests are therefore regeneration fellings, badly stocked places where light is admitted, especially in older woods and in woods of light-demanding species; and, finally, blanks, unfrequently used roads, and places for stacking timber, road-sidings, and so on.

iii. *System of Management.*

Pollarding is adopted rather with a view to pasture than to the production of wood, and grassy tracts on rich, fresh soil along the banks of streams are, under this system, sheltered by willow- and poplar-pollards, grown pretty far apart, and the production of grass is thus generally favoured. Provided the same species of trees are grown; next to pollards, coppice produces more fodder than any other system, and coppice-with-standards approaches coppice the nearer, the less standards it contains. Coppice and coppice-with-standards, for the same area, produce at least five or six times as much fodder as high forest. The last form of forest, especially the clear-cutting system, is the most unfavourable for pasture.

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* The grass in many larch-woods in the Alps is regularly mown.

iv. *Climate.*

In mild climates the production of fodder is greater than where extremes prevail. In the former, grazing may commence at the end of April or the beginning of May, and continue till the middle of October, whilst in the latter, the season for grazing is much more restricted, and in upper Alpine pastures may only last 10—12 weeks. During May and June there is most fodder in forests; in high altitudes, in July. In these months grass production is greater than during all the rest of the year.

(b) Quality of Forest Fodder.

As regards its quality as fodder, the amount of light which herbage receives, and the nature of the soil, are more important than the species of plants of which it is composed.

The excellence of Alpine pastures depends less on the indigenous[*] plants (for in the North German plain and Holland equally fine cattle are produced as those in the Alps) than on the advantage resulting from constantly keeping the cattle in the open air, the moderate distances to which cattle are driven to graze, and the effects of the intenser sunlight to which these lofty open pastures are exposed. On this account, provided there is sufficient moisture, southerly aspects yield better pasture than northerly aspects. The more the soil is sheltered by trees, and the less light it receives, the poorer the quality of the fodder; hence regeneration-fellings and plantations, on protected soil yield the best fodder. It is well-known that forest pastures yield the best fodder before the herbage has blossomed.

[*] The best Alpine fodder-plants for milch-cattle are:—*Poa alpina*, *Alchemilla alpina*, *Plantago alpinus*, *Meum mutellina*, *Achillea moschata*, &c.

3. *Effects of Pasture on Forest Management, and Conditions under which it may be tolerated.*

At the present time it is very difficult to pasture cattle in forests without danger to the latter. Although sometimes the forest may thus profit in certain ways, and the magnitude of the danger to which it is exposed may vary, yet in the majority of cases pasture is a great hindrance to the productiveness of forests.

(a) Advantages of Forest Pasture.

In only a few cases does forestry gain any advantage from pasture. These should not, however, be overlooked; they consist in the suppression of dense growth of grass and herbage in regeneration-areas and plantations, in protection against mice, and, to some extent, in keeping the surface-soil free for the germination of seeds.

There are many sheltered regeneration-areas with moist and rich soil, on which, after only a moderate admission of light, such a strong growth of grass appears that the woody plants under it must be stifled if the herbage is not carefully removed. It is chiefly shade-bearing species of slow growth when young, such as the beech, silver-fir and spruce, which thus suffer to any considerable extent, and for which the admission of cattle on to the area may be advantageous. In higher altitudes large-leaved herbs spring up among the tufts of grass and, especially on moist soils, form such a dense mass of vegetation that the young woody plants must perish were it not for the intervention of cattle. It cannot be denied that in the Schwarzwald, the Harz, &c., many young plantations and woods owe their existence to cattle-pasture. Similarly, in the Central German mountain ranges, as, for instance, the Vogelsgebirge, natural beech-reproduction can be secured against the luxuriant growth of grass only by the help of cattle-grazing. In recommending the admission of a moderate number of cattle into reproduction-areas in order to keep down a stifling growth of grass and herbage, it should be remembered that this is only applicable when the latter threatens the existence of the young woody plants, and cannot be removed by other means than the admission of cattle; and that, on the other hand, there are dangers connected with grazing with which, in certain cases, the advantages already described are not commensurate. As with grass and herbage, so also with aspens and sallows, which may often be kept down by grazing.

Frequently, danger from mice follows from a dense growth of grass, especially in felling-areas near fields. Under and between the dry procumbent tufts of grass the mice find sheltered winter quarters, where they collect in swarms, especially under deep snow, and cause great damage to young beech and other plants by gnawing their bark.

It has been observed in many places, that in scantily-stocked old woods with consolidated soil, where cattle have pastured, natural regeneration is more easily obtained than in others closed to grazing, provided the cattle are removed when the seed germinates. This is due to the **wounding of the soil**, caused by the tread of the cattle, especially on somewhat sloping ground.

(b) Disadvantages of Forest Pasture.

The realisation of the above-mentioned advantages from forest pasture is always more or less attended with danger to the forest. Before deciding on the admissibility of pasture to a forest, one must be acquainted with the means of meeting these dangers, and the sylvicultural rules to be enforced to keep the grazing within proper limits. The damage which cattle effect in a forest is chiefly due to **impoverishing the soil, browsing** on the forest plants, and **trampling** on their roots and on the soil. Besides the injury due to hardening of the soil, the dung which collects at the resting places and night-resorts of the cattle, is said to cause red-rot or other diseases; but as a rule these consequences are inconsiderable or doubtful [whilst the dung may frequently be sold.—Tr.].

i. *Impoverishment of the Soil.*

Every usage which removes forest produce must consequently reduce the fertility of the soil; it is incontestable that pasture removes, in the fodder consumed, large quantities of nutritive mineral matter from the forest and reduces the organic matter necessary for the formation of humus. It is difficult to say to what extent this deprivation of nutriment is replaced by the dung of the cattle.

ii. *Damage by Browsing.*

Cattle not only graze on the grass and herbage of the soil-covering of forests, but also browse on the leaves, buds, and young shoots of woody plants, to an extent which will be considered below. That, by this browsing (especially if repeated annually for long intervals of time) forest growth is seriously damaged and its very existence endangered, may be proved by the present condition of hundreds of acres of forest, even if the fact is not accepted as self-evident. When and where browsing is to be feared, and the extent to which woods are thus endangered. depends on the larger or smaller **supply of fodder-plants** on the grazing-grounds, the **species of cattle admitted to graze,** the **susceptibility of the woody species,** the **season for grazing,** the **age of the woods** and the **system of management.**

Supply of Fodder.—It is obvious that when cattle do not find sufficient grass or herbage on their grazing-grounds, they will attack woody growth. Thus, when cattle are driven into young plantations to remove a dense growth of grass, the young forest plants are secure from serious danger until the grass has been sufficiently grazed-down.

It is evidently necessary to base the number of cattle admitted to graze in a forest on the amount of available fodder it contains. Very many Alpine forests, for instance, have suffered greatly from an excess in the number of cattle admitted into them by grazing-rights. As a rule, the requirements of fodder per head are proportional to the weight of the beasts ; thus, a cow of average size, weighing 200 kilos (4 cwt.), requires daily for its complete nourishment 7—8 kilos (15—18 lbs.) of hay ; if, as Hundeshagen calculates, for every cwt. 1·8—2 kilos (4 to 4½ lbs.) of fodder are necessary. If calves are reckoned at two-thirds and sheep at one-tenth the weight of a full-grown cow, 5 kilos (11 lbs.) of hay are required for a calf, and ¾ kilo (1¾ lbs.) for a sheep. It is impossible to say what is the average yield of fodder in forests open to grazing, but grass, equivalent to 700—900 kilos of hay per hectare (5½—7 cwt. per acre), may be cited as the supply in good localities.

Species of Cattle.—Forest pasture is chiefly used by horned cattle ; also by sheep and goats, and less frequently by horses or ponies. [In India, elephants, camels and buffalos may be added to the above list.—Tr.] Among these, horned cattle do the least damage, for they prefer grazing on the ground, and as long as there is sufficient grass and herbage, will not attack the woody plants. The sheep likes dry pasture, and prefers short grass among woody plants to a strong, luxuriant growth of grass, and especially prefers fodder which has grown unshaded by trees; it attacks woody plants much more freely than horned cattle. If there are no dry pastures, sheep nibble the trees in a similar way to red deer. The goat is absolutely destructive to the forest, and no other beast shows such a preference for woody plants, which it will attack, however abundant the supply of grass may be. This greedy beast, often indeed indispensable to the poor peasant, bites off the buds, young shoots, and leaves of almost every woody plant within its reach; no forest is too remote for it, and no mountain too lofty, no patch of woody growth beyond its reach, and it even bears-down fairly tall saplings with its fore legs, so as to nibble their juicy tops. Forests in the Alps, the South Tyrol and Southern Switzerland, which were formerly so well wooded, and those of Spain, Greece, Sicily, &c., have been destroyed chiefly by herds of goats; even up to the present time a limit has not been put to their ravages.*

Young cattle are always more harmful to the forest than older beasts; even calves form no exception to this rule, nibbling woody plants partly out of playfulness, partly to assist dentition. Whilst a flock of full-grown sheep may be driven without much danger through a beech or spruce reproduction-area well stocked with grass, as is sometimes done in the Harz, this can never be the case with lambs.

The condition of the animals as regards fodder is of immense importance to the well-being of the forest. Hungry cattle, of any kind, will attack woody growth much more readily than those which are well fed; if, therefore, there is only scanty herbage in a forest, the damage done by either horned cattle or sheep may be considerable. It is on this account that the half-starved flocks of sheep driven annually from Lombardy to the

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* Compare the excellent pamphlet on grazing by goats by Dr. Funkhauser, Berne, 1887.

Engadine and the Tyrol are always so destructive to the forests. So, also, cattle reared from their youth in forests attack woody growth much more than cattle accustomed to meadows and only occasionally driven into the forest. Milch and breeding cattle always require the best fodder, and satisfy their hunger without wandering far; young cattle thrive on inferior herbage, and it is even beneficial to them to be driven far into the forest for their fodder.

Species of Tree.—In general, broad-leaved species suffer more from cattle than conifers; among them, it is (unless they possess acid or bitter sap) the quick-growing, sappy and chiefly light-demanding species which are most attacked, such as ash, aspen, sallow, sycamore; also hornbeam. These species are attacked when mixed here and there with beech, even where there is plenty of herbage. It is characteristic of cattle to prefer locally rare woody species to those of which a wood is chiefly composed. Whilst in districts where beech predominates, it rarely suffers provided there is plenty of grass, beech-plants springing up in coniferous woods with scanty herbage are so freely attacked as to grow into abnormal shapes, which can be hardly recognised as trees. The steady diminution and approaching extermination of beech and silver-fir in the Alpine forests are due, partly to the clear-cutting system, and partly to forest pasture. Oak and alder are less liable to attack than the species already mentioned, and except the alder, the birch is the only European forest tree which is rarely browsed by horned cattle. Sheep spare beech more than horned cattle, but they attack light-demanding species freely, even the birch. The goat is impartial in its taste for woody species. Among conifers, silver-fir and larch are more endangered than spruce and the various species of pine, which latter suffer least from browsing. The spruce escapes more easily than the softer silver-fir; the larch grows most rapidly out of danger, as the larch forests of Wallis and the Engadine show.

Season for Pasture.—Pasture is most dangerous to woody growth at two periods of the year: first, in the spring, when the young shoots appear and the foliage is tender and most nutritive; again, late in the autumn, when the grass has become hard or scanty. The least damage is therefore done at the season when the grass is still soft and juicy, and the annual upward growth of the woody plants is about finished, *i.e.* from the end of May till the middle of July. In the higher Alpine pastures, however, the grass is not fully grown till the second half of June. If cattle are brought into the forest only when the grass has become tough and there is little after-growth, they will certainly browse on woody plants. Cattle should not be driven into the forest in the morning before the dew has nearly dried from off the grass, or else they will attack the woody plants; they will also do so in wet weather.

System of Management.—The damage done by pasture is very slight in even-aged woods, provided the cattle are only admitted into compartments where the trees have grown beyond their reach, and all young woods are closed to them. Plantations suffer much more from browsing than natural regeneration or sown areas, where the plants are much more numerous. The comparative duration of the close-time depends on the rate of growth of the young plants, and therefore on the quality of the locality, the species of tree, the nature of the wood (whether from seed or plantation), the kind of wood (coppice or high forest), and also the species of cattle. Selection woods appear, at first sight, to be less favourable for pasture than those which are even-aged, for in them regeneration is carried on at the same time all over the forest. When, however, cattle remain night and day in the forest without herdsmen, as in most Alpine regions, selection forest withstands the danger better than even-aged woods. Even-aged, densely-stocked spruce forests are destitute of herbage, which is found only on the reproduction-areas that are closed against cattle. It is, however, a matter of everyday experience that no amount of care in fencing will always protect these areas. In natural regeneration in a selection forest, not only is there far more fodder produced, but damage by cattle is more widely distributed.

If the close-time for young woods is prolonged until the crown of the woody plants is beyond the reach of the grazing animals, there can be no object in admitting them to the forest, for in dense even-aged woods of poles and saplings there is no herbage. The forester has, therefore, no interest now-a-days in the question of a permanent close-time for a wood. On the other hand, the existence of rights to pasturage necessitates an enquiry as to the possibility of admitting cattle into young natural regeneration-areas. In some districts this is considered not only allowable, but even advisable; whilst in others there is no privilege to which the forester is more opposed than pasture in felling-areas. Grazing is therefore admissible only when the herbage is so dense as to threaten the very existence of the woody growth. If in such cases a small herd of cattle, or even a small flock of sheep, is admitted in dry weather, and when the grass is still tender and nourishing (usually before Midsummer-day, or, in the Alps, during July); if the cattle are not half-starved, and not accustomed from their youth to forest pasture; if they are driven gently and not every day in the same direction, and are kept under strict control by the herdsmen; if they are withdrawn from the wood as soon as they have satisfied their hunger, and not allowed to lie-down—then, in most cases, on the grounds of both general and sylvicultural utility, the damage done will be slight in comparison to the advantage gained. It cannot be denied that in the most favourable cases hundreds of woody plants will be nibbled or trampled-down; and that in beech-woods, with a few disseminated ash, sycamore, oak, and other saplings, these plants and especially the oak will suffer: but if too many plants are not thus sacrificed (when one considers that most of those injured will recover, and also how many forests which have been open to pasture, especially extensive tracts of Alpine beech and spruce-woods, and yet have grown into splendid woods), the conviction cannot be resisted, that pasture need not be entirely excluded from felling-areas when they are richly stocked with grass. It appears obvious that grazing cannot be allowed in artificially planted or sown areas, where the number of plants is necessarily reduced to a minimum; yet cases have occurred in Russia (Poretsche), where grazing has proved beneficial to plantations with a dense growth of grass.

iii. *Damage by Trampling.*

It is evident that young plants must be damaged when trampled by the hoofs of heavy cattle; colts and fillies are most hurtful in this respect; sheep also, owing to their sharp hoofs and short stride, in spite of their comparatively light weight, may do much damage. Besides trampling-down young plants and shoots and bruising young superficial roots, calves jump about and crush saplings and poles. The amount of damage done, however, is modified by the configuration of the ground.

On level or gently sloping ground the damage done by the tread of cattle is only slight; on slopes, however, both horned cattle and sheep, when grazing in narrow strips of forest or passing daily in the same direction, make a network of narrow paths, which intersect in all directions on dry slopes where the grass is scanty. The effects of trampling are, however, much worse on steep, damp slopes, with marshy patches, the cattle at each step slipping and making grooves in the surface-soil, and burying every plant in their way. In damp, scantily turfed felling-areas with a deep moist coating of humus, which frequently occur on the north sides of mountains, this kind of damage attains its maximum in the case of heavy cattle, after prolonged rainfall; a very few cattle then suffice to destroy the re-growth on a felling-area. After the soil has settled-down and become overgrown with grass, and the plants are somewhat larger, this form of damage is less formidable. It is obvious that heavy beasts do more damage by their tread than smaller ones. Their degree of hunger is so far influential that, once satisfied, the herd comes into close order, no longer moves leisurely onward and its tread is far more dangerous than when the beasts roam individually in search of fodder. In pasturing cattle on young reproduction-areas, therefore, these peculiarities should be taken into account.

(c) **Money Value of Forest Pasture.**

It is extremely difficult to ascertain the money value of forest pasture, although this must often be done in order to fix compensation for grazing-rights; a thorough knowledge of all the local circumstances of the case is then essential. The greatest difficulty is to compare the nutritive value of forest pasture with that of hay. This ratio varies considerably, showing that serious errors may be made in roughly estimating the value of forest pasture. The annual value of a right to pasture cattle in a forest can be readily ascertained only in particular cases, by considering how much rent the farmer would have to pay to secure equally good pasturage outside the forest.

SECTION II.—GRASS-CUTTING.

Whilst forest pasture is steadily diminishing owing to the increase in the stall-feeding of cattle, grass-cutting is gaining ground in like measure. This is especially the case in places where agriculture is most profitable. The small farmer (and even the peasant living close to forests) is gradually learning the advantage of feeding beasts in stalls; consequently, the supply of manure and the demands for forest grass are constantly increasing, for the increase in fodder-crops and meadows does not keep pace with the increased number of beasts fed in stalls.

If the full value of the grass cut in Germany from forests could be given, its immense national-economic value would be thoroughly appreciated; it would be seen that a very considerable number of cattle obtain their summer fodder almost entirely from forests, and that the maintenance of the poor man's cow or goat is often only thus rendered possible. From the Hardtwald near Mühlhausen in Alsace, for instance, the annual crop of forest grass is estimated as at least 2,500 tons. There are also forest ranges in Prussia, which obtain annual revenues of 750*l*. to 900*l*. from grass; in the forest range of Berghausen, in Baden, the average revenue from grass during 5 years has been 760*l*. (6*s*. an acre). Any forest range situated in a populous district and where the soil is moist, especially if treated as coppice, or coppice-with-standards, can yield even larger returns. In the dry year 1893, no less than 65,000 tons of grass were obtained in a regular manner from the Bavarian forests. About as much was probably taken from them fraudulently. The advantages the forest gains from grass-cutting are similar to those already described under pasture. Plantations and natural regeneration-areas are saved from being choked by the grass, and from deprivation of light and dew; whilst damage by mice is greatly reduced, and finally, a considerable revenue is frequently obtained.

It should not, however, be forgotten that by the removal of so much organic substance from the forest, the productive power of the soil is impaired; for grasses often contain large quantities of ash, especially at seasons when they blossom and their seed ripens. More mineral matter is therefore taken from the soil when the grass is cut and removed, than when litter is utilized, and only moist rich soil can withstand this. On poor soil the practice must not be adopted. Persistent grass-cutting for a series of years on poor soil reduces not only the production of wood, but even of the grass itself, which eventually disappears.

Localities, which under the influence of the factors referred to in the first section of this chapter produce large quantities of grass, may be distinguished as **permanent**, or **temporary, grass areas.** To the former belong regular **forest meadows,** which owing to their naturally moist condition are adapted for a prolonged supply of good grass. **Temporary grass-areas** include all those destined for the production of wood, but which, during the young stages of woody growth, are adapted for the production of grass ; besides these, all **blanks** in the forest, such as the **sides of ditches, road-sidings, fire-lines** and other similar places may be here included, which unlike permanent meadows are not kept clear from woody plants expressly for grass-production.

The **permanent grass-areas** are lands contained in the forest area, but used for the production of grass: these are lands liable to inundations from rivers and brooks or near permanent springs which afford the necessary supplies of subsoil moisture ; lower parts of valleys between mountainous slopes ; Alpine pastures or similar areas with rich moist soil in mountainous countries. Wherever there are extensive areas of this nature, and fodder is scarce, every means should be employed which the farmer uses to improve his meadows ; often only a small expenditure is necessary to obtain a better crop of grass by removing stones and rocks, draining swamps, or planting rows of trees far apart. It is not only the direct utility to the forest which should be considered by the forest manager, but public duty also should impel him to endeavour strenuously to increase the local supply of fodder, especially in essentially forest districts where the poor peasantry are constantly increasing in numbers and becoming more and more impoverished.

For a **temporary supply of grass** the most important places are :—areas of recent fellings ; plantations with moist, grass-producing soil (especially 1 to 5 years old beech and spruce regeneration-areas, and 1 to 3 years old fellings in coppice or coppice-with-standards) ; also alder, ash and larch woods of almost any age, which usually produce good crops of grass. In some places, clear-felled areas are used for the production of grass several years before being replanted. Grass-cutting among young plants causes much anxiety to many foresters. There is a danger that many young plants may be cut with the grass, so that to forbid grass-cutting altogether may appear to be the simplest remedy. By so doing, however, a valuable product is withdrawn from people who are in general greatly in want of fodder, and a source of danger to the young woody plants is not removed, whilst the most stringent regulations and laws will not prevent poor people from stealing the grass. Then, owing to hasty cutting or to the fear of inevitable punishment, it will be cut without the slightest care for the forest plants. Grass-cutting is therefore, as a rule, advantageous to the forest, provided the soil is sufficiently good to permit the practice on felling-areas and among young growth, on condition that it is carefully cut and removed. This is specially important in years of local scarcity of fodder. On the other hand, all poor dry soils should be excluded from this practice, especially in lightly stocked coppice and coppice-with-standards ; for besides the fact that the grass-crop is scanty in such places, its removal must be considered as a great drain of nutriment from the soil.

On all permanent forest grass-lands, the grass is mown with scythes as in ordinary meadows ; where the presence of trees would interfere with the scythe the sickle is used instead. Forest revenue is obtained either by leasing the grass for longer or shorter periods, or by selling the crop in well demarcated lots by public auction. The grass among young growth or on felling-areas may be either plucked by hand or cut with the sickle. Hand-plucking is considered a less hurtful method, but it yields little and cannot be continued long without danger to the hands. Cutting grass is nearly everywhere effected with the common smooth-bladed sickle, and but rarely with the saw-toothed one. It is difficult to prove that the sickle is always a dangerous instrument among young growth, for both plucking and reaping must both be carefully done. Where the plants are small and the grass tall, reaping is less dangerous than plucking; when the plants are taller, they can be easily seen and are as easily avoided with the sickle as with the hand. On very wet soil and where plants are subject to frost-lifting, for instance, on basalt covered with deep humus, reaping is better than plucking, as the latter dangerously loosens the soil.

The season for grass-cutting cannot be begun too soon when plants are being choked by the grass. In any case, a commencement should be made no later than the blossoming period; and if, as on very rich soil, it is necessary to repeat the cutting, this should be done during autumn, for the snow will press down the grass over the young plants in winter and thus endanger them.

Grass-cutting on felling-areas is thus not only permissible with good supervision and goodwill on the part of the workmen, but in most cases is preferable to absolute refusal of permission to cut. The revenue for it is collected either by the issue of cheap grass-permits, giving the holder a right to cut grass on certain designated areas, or by auction-sales of demarcated lots of grassy tracts. This latter plan is suitable in the case of moist coppices and coppice-with-standards along the banks of large rivers, where there is usually a dense growth of grass.

SECTION III.—LEAF-FODDER.

The foliage and young shoots of woody plants may be used in a similar way to herbage for cattle-fodder. The value of leaf-fodder, however, varies with the season of the year: as long as the foliage is incompletely developed its value as fodder is highest; it continually depreciates after the foliage is fully grown, and is lowest just before leaf-fall. The species of trees which are most exposed to damage by the browsing of cattle, furnish the best fodder; after the Canadian poplar, which is best of all, are ash, poplar, willow (especially *S. alba*, *caprea*, *vitellina*, and *pentandra*), lime, sycamore and other maples, oaks, and (as long as their foliage is young), beech and elms. Among conifers, yew and silver-fir are favourites [the former may be injurious.—TR.]; even the spruce may be used, last of all the larch. The kind of beast must also be considered, for goats and sheep will eat any broad-leaved species, whilst horned cattle are more discriminating; as a rule, leaf-fodder serves in Germany for the winter food of sheep and goats. The remark is hardly required, that the use of leaf-fodder is highly prejudicial to the growth of trees. A tree can only dispense with its foliage after the processes of transformation and assimilation are over, and that is shortly before leaf-fall. As, however, the nutritive value of foliage [other than that of evergreen trees and shrubs which store nutritive material in their leaves during winter.—Tr.] late in the autumn is very small, and farmers wish to use it as early as possible, the use of leaf-fodder must, from a forest point of view be regarded as highly prejudicial. Little is to be gained by permitting foliage to be plucked only after the buds have been formed for the succeeding year's crop, for the preparation and storage of reserve nutritive material for that year's wood is thus prevented. With the exception of a general scarcity of fodder, when in many districts the foliage of trees afford the only means of saving the lives of the cattle (in Hungary 1863, Fichtelgebirge 1887, and France 1893), the use of leaf-fodder should as far as possible be prohibited. In Switzerland (Canton Wallis) oak-pollards are regularly lopped for goat fodder.

[Similarly, in the centre and south of France. In the Himalayas, evergreen oaks, elms, wild plum-trees, *Celtis*, &c. and even spruce-trees are regularly pollarded for cattle-fodder, and the practice prevails with other species in various parts of India. Rules on this subject, for the protection of the trees, are given in Manual of Forestry, vol. 4, p. 25.—Tr.]

Leaf-fodder is harvested chiefly in coppice and from pollards, the leaves being either plucked by hand, or the young shoots cut, tied into bundles and dried quickly in order to prevent the leaves from falling. The wilting twigs and foliage are placed under cover in an airy place, or kept in loosely piled stacks. One hundred and fifty kilograms of leaf-fodder (330 lbs.) exclusive of branches, is considered equivalent to 100 kilos (220 lbs.) of hay of average quality; a bushel of leaf-fodder, including twigs, contains, for oak, 40 %, for sallows, 60 % of nutritive substance. In the lower Rhine-valley, and along the Moselle, leafless twigs and young shoots from oak-coppice are used in years of scarcity for sheep fodder.

In districts where broad-leaved forests abound, the use of leaf-fodder is unimportant, for where there are extensive forests there is also abundance of grass, and a scarcity of fodder is very exceptional (as in 1893). Leaf-fodder is, on the other hand, of great importance where there are few broad-leaved forests; as, in most Tyrolese valleys, in some districts in Switzerland and on the Eifel, in districts where large flocks of sheep are kept and there is a permanent scarcity of other than leaf-fodder. Leaf-fodder is also regularly used in parts of the Alps, Dalmatia, and some Hungarian districts, &c. [Also in most of the countries bordering on the Mediterranean Sea.—Tr.]

CHAPTER III.

FIELD-CROPS IN COMBINATION WITH FORESTRY.

When field-crops are grown on forest land they are classed as minor forest produce. Either the field-crop or the crop of wood may preponderate in value, and the methods adopted vary in accordance with their comparative importance. These different methods will now be considered seriatim, chiefly from a sylvicultural point of view.

Section I.—Methods Adopted.

1. *Lands permanently cleared in Forests.*

Forests contain certain lands which are always free from wood, and are consequently classed as sylviculturally non-productive. These are fields given either rent-free or at a low rent to forest guards or to permanently engaged woodcutters; areas cultivated for feeding deer or other game; areas adjoining foresters' houses in the interior of forests, which are cleared to afford sufficient light, heat, and air to render them habitable, and to afford space for gardens, orchards, or field-crops. Road- and railway-sidings, and blanks left unstocked with trees for sporting and other purposes may be included.

As lands thus excluded from the wood-producing forest area (except those used for feeding game) are rarely cultivated by the forest owner, they should be leased unless they are allotted to forest officials or woodcutters.

2. *Field-crops grown on Woodland without care for forest growth.*

Formerly in certain localities where the value of wood was almost nil, it was often customary to fell and burn the trees, and then cultivate the soil for agricultural crops as long as these would grow without manure. The land was subsequently put under pasture. It then became gradually restocked with trees by means of coppice-shoots and seeds coming from adjoining woods.

In Europe this barbarous manner of destroying forests and using the burned area for field-crops or pasture is still followed in Finland, Northern Sweden, certain parts of Russia and here and there in the Alps and Carpathian mountains. In other localities a regular utilisation of the wood has been introduced, only the unsaleable parts being burned, as well as the shrubs and soil-covering. Such a system is still in force in the Swiss cantons of Luzern and Wallis. The wood on these areas is felled every 10—20 years, the stumps extracted, and the refuse burned ; potatoes or corn are then grown for a few years, when the land is abandoned to forest growth or used for pasture. Gradually, woody growth reappears, and after a number of years the same treatment is repeated. In the district of Birkenberge in Lower Bavaria, a similar system, now falling into disuse, was followed in woods chiefly stocked with birch and spruce trees; but in this case, a few standard trees were left to give seed, and the land constantly subjected to pasture and removal of litter after 2—3 years of potato or corn crops had been harvested. Some districts of the Reutberge in the Black Forest may be mentioned here, as the cultivation of trees is quite subordinated to that of field-crops. Some of the better tracts in the Reutberge are, however, managed more in accordance with the system which will be described in paragraph 4.

[In many hill-districts in India, a similar custom, termed **jhuming,** prevails. As an instance, the mode adopted in the Garo Hills, south of the Brahmaputra river, will be described. The Garo village-communities own land naturally stocked with trees, bamboos or grass. In October they fell all the woody growth on areas they wish to cultivate, and cut the herbage, &c., reserving a few large trees, if found on the area. Sometimes they remove a certain number of poles and other pieces of wood or bamboos for their own use, or for sale in the plains of Sylhet, and the rest of the wood is spread on the ground, and burned in March. The stumps are not extracted, but the land hoed between them and cotton or rice sown. In the second year, a crop of yams, chillies, tapioca, &c., is taken off the land, and then the area is abandoned to woody growth from coppice-shoots, seedlings, &c. In about ten years or less, according to the total area of land possessed by the village, the operation is repeated. The Garos levy fines on a village if a fire should spread from its lands to those of another village. The reserved trees are lopped of most of their branches, so as not to overshade the crops, and temporary bamboo huts are built in the forking boughs of these trees, where the cultivators can sleep without fear of elephants and other wild beasts.—Tr.]

3. *Field-Crops alternating with the Cultivation of Trees.*

Wherever care is taken to protect the woody growth after the field-crop has been harvested, the latter may be considered as subordinate in importance to the former. Here, usually after a clear felling, unless the trees have been up-rooted, the stumps are extracted, the refuse burned, and the soil cultivated for a crop of corn. If the soil-covering consists of shrubs, grass, &c., it is sometimes hoed-up in sods and burned in loosely piled heaps with the wood-refuse. The heaps are thoroughly burned to ashes so as to leave as little charred wood as possible. The ashes and the burned earth from the sods are then strewn over the area. This system is termed in German, *Schmoren* or *Schmoden*. If the area is merely roughly hoed, and all the herbage and refuse wood spread over it so that the fire passes over the whole area, the system is termed *Sengen*. This is usual when there is not much herbage on the soil, the soil-covering chiefly consisting of coniferous needles; the fire is then applied against the wind, or downhill on slopes, otherwise it would be kept under control with difficulty.

In the system termed *Schmoren* the refuse is more thoroughly burned to ashes than in the latter system, which produces more charred wood. The beneficial effects of burning the soil are, however, more marked in *Sengen*.

The field-crops usually last for two years. Generally cereal crops are cultivated, buckwheat, rye, or oats, a third crop being sometimes obtained. [Potatoes are also grown.—Tr.] The ground cannot always be cleared early enough for spring sowing, it then lies fallow till the autumn, when it is sown for the next year's crop. As soon as the cultivation of field-crops ceases, the area is restocked with trees either by sowing or planting, and occasionally the seed of the trees is sown with the last cereal seed.

There are several varieties of this mode of treating forest land.

Thus, in many Scotch pine districts, the felling-areas with reserved standard trees standing on them are leased in lots for one year's cereal cultivation, in order that the soil may be thoroughly loosened for natural regeneration of the Scotch pine. The soil must not then be too matted with weeds or roots if the cost of cultivation is to be covered by only one year's crop. In some cases, in order to supply a certain amount of transitory freshness to a poor, dry, sandy soil, the area after cultivation is sown with lucerne, which is cut-down and ploughed-in as soon as it is in full bloom; corn is then sown, and in the third year either Scotch pine seed sown, or another fodder-crop of lupines harvested before this is done. As now-a-days Scotch pine culture is frequently combined with that of field-crops, so it was formerly the case with pure oak-woods. In nearly all German countries there are forest compartments termed acorn gardens (*Eichelgärten*), which were formerly cultivated with field-crops for several years, acorns being sown with the last crop, and the area again surrendered to forestry. In Upper Bavaria spruce plants with balls of earth round their roots are planted in land which has been cropped with oats. The land is cleared, cultivated, and oats sown in the spring. In the second year a crop of potatoes is reared; in the third year another crop of oats mixed with spruce seed. From the fourth to the sixth year the spruce seedlings are utilized as transplants with balls of earth, and planted in lines on the area and on other neighbouring cleared strips.

4. *Simultaneous Cultivation of Forest and Field-Crops.*

In the above-mentioned systems the felling-area is abandoned to agriculture for several years, and the cultivation of a forest crop commences only after the last field-crop has been harvested. The wood-increment is therefore lost during the years occupied by the field-crops. There are, however, other methods in which there is no interruption in the production of wood, and the field-crop is merely intended to assist the latter. The two most important varieties of this method are termed in German, *Hackwald* and *Waldfeldbau-Betrieb*.

(a) **Hackwald.**—This is a combination of field-crops and coppice, nearly always of oak; it has been practised for centuries in the Odenwald, Siegen, Westphalia, Hildesheim and several other localities, and is most extensively followed in the district of Beerfelden and Hirschhorn in the Neckar-valley. As soon as the oak-coppice compartments have been felled and peeled, the bark removed, and the felling-area cleared (usually about the end of May), the felling-area, on which the oak-stools are somewhat far apart, is cultivated by hoeing and burning, as in the previously described methods. At present, in the Odenwald and in Siegen the cultivation is only for a single crop, and the area is sown with winter-corn (in October or November). In Siegen a light plough, or cultivator, is used before sowing. The harvest follows in the succeeding year, and the felling-area is then left for the coppice to grow up. In the third year, broom generally appears, which is used as farm-yard litter. Sometimes in Siegen the felling-area is grazed in the third year by sheep, but as a general rule by cattle, till the 6th year or later.

In the Odenwald an acre of the best *Hackwald* yields about 8¼ bushels of grain. The felling-areas are leased in small lots for cultivation either after the felling and clearance of the wood and bark, or together with the wood and bark. In Hirschhorn and Beerfelden the forest owners first auction-off the bark to tanners at so much a cwt., and at the same time the right of cultivation in small lots to the peasantry; the latter also buy the standing-crop, bark and wood, and the right of cultivating as well, under agreement to sell the bark at a stated price to the tanners (see p. 503). In Siegen an acre yields on the average 13 bushels of grain. The right of cultivation is here exercised on the annually felled areas by an association of peasants. There has recently been much less demand for *hackwald* cultivation, as more grain is imported, and peasants find remunerative employment away from their native villages; the landowners are therefore compelled to make an allowance to the coppice purchasers to induce them to cultivate the soil, and thus increase the production of bark.

(b) **Waldfeldbau.**—*Waldfeldbau* is a similar method to that of *Hackwald*, but is applied to high forest instead of coppice. The method adopted by *Forstmeister* Reiss of Hesse-Darmstadt has been exactly followed in different German countries, and the following account of the experience gained in the well-known forest range of Viernheim will suffice to explain it. The felling, and clearance of the felling-area is hurried-on so that the land may be cultivated early in the spring. All the wood is uprooted except a few standards (oaks or Scotch pines). The whole cleared felling-area is cultivated to a depth of from 1 foot to 16 inches, and the thoroughly worked soil restocked by sowing, or by planting in lines 1½ meters (say 5 feet) apart. Oaks or conifers are used for this purpose, according to locality. For oaks, acorns are sown 3 meters (10 feet) apart; at the same time Scotch pine nurses are planted or sown in rows to protect the oaks, and are eventually removed in thinnings. The rotation is fixed at 100 years. In the intervals (4 feet broad) between the plants, field-crops are grown on the better soils for 4 years and on poorer soils for 2 years.

In the first year it is usual to grow a crop of potatoes, in the second year, winter-corn; and if the field-crops are continued during the third and fourth years the same order is followed. When the potatoes are dug the intervals between the forest plants are also hoed, weeded, and the plants almost as carefully tended as if they were in a forest-nursery. If in the first year there should not be enough plants or seed to stock the ground, the whole area is cultivated for a potato-crop, and, as an exception, the restocking only undertaken in the autumn.

In Hesse about 10,000 acres of forest land have been thus treated. In Württemberg also, this system has been extensively adopted, especially on a rich soil near Bibrach. The method has also been tried in the Prussian provinces of Pomerania, Silesia, Hesse-Nassau, and in Alsace-Lorraine; in some Bohemian districts; in Hungary, where also crops of maize are reared. At present, however, the agricultural aspect of this system has greatly lost in interest for well-known reasons.

SECTION II.—NATIONAL-ECONOMIC IMPORTANCE OF FIELD-CROPS COMBINED WITH FORESTRY.

The national-economic advantages of combining field-crops and forestry consist in the increased production of food, the fact that this can be secured without any manure, and last but not least, because the increased supply of straw really increases the amount of manure available for agriculture. These advantages, however, depend in the first place, on conditions of climate and soil being favourable to agriculture; secondly, on sufficient facility in the cultivation of the soil, and the possibility of obtaining a sufficient supply of labour.

Field-crops make greater demands on both **climate and soil** than forest plants; in order, therefore, that they may thrive, suitable climatic conditions are essential, and this, experience has fully proved (as in the Rhine-valley, Switzerland, Bohemia, and some districts bordering on the Danube). The demands which field-crops when continued only for a few years make on the fertility of the soil are more easily met, for only a moderate and superficial supply of nutritive soil is requisite, which every forest soil possesses, provided it has not been deprived of litter and its degree of compacity does not offer too great obstacles to cultivation. As regards locality, the **gradient** of the area to be cultivated is often steep, and deep cultivation cannot be effected without danger of denudation by rain-water. It is therefore essential, if field-crops are to be grown with profit, that the area be level, or only slightly inclined. Another condition is that the land shall be not **too remote** from the labourers' houses, a highly important point now that wages are so high. The **amount of labour** involved in the cultivation naturally varies with the stiffness of the soil, the amount of herbage which binds it together, and whether the roots of the woody plants have been extracted or not beforehand. The duration of the agricultural treatment also greatly influences the question, for it can hardly prove remunerative to remove the stumps and roots of felled trees for the purpose of cultivating a piece of ground for one year's crop only.

Scarcity of Land for Cultivation and a Dense Population are also necessary conditions; where sufficient cleared land is available for agriculture, and plenty of other work is available, the peasants cannot be induced to cultivate remote forest areas. If the forest owner attempts to cultivate at his own expense it is evident that labour must be plentiful, or he will not get sufficient workmen. Matters of late years have greatly altered in this respect. Formerly it was only possible for the dense population of many mountainous districts to obtain sufficient food by supplementing the crops from their own poor lands by those taken from adjoining forest field-crops, as they could not possibly purchase imported grain. The present increased facilities for traffic, the great demands industries make on labour, the small returns of agriculture and many other circumstances have in most districts greatly reduced the desire for forest field-crops, and in a few decades they will probably be abandoned.

SECTION III.—SYLVICULTURAL IMPORTANCE OF FIELD-CROPS IN FORESTS.

The question now arises as to what forestry may gain or lose by a combination of field-crops and tree-growth.

1. *Advantages to the Forest.*

The two chief ways in which a forest gains from field-crops are: the consequent increase in the forest revenue, and the reduced cost of reproduction; for the ground is thus cultivated and the growth of the young plants stimulated.

(a) **Increased Forest Revenue.**—As agriculture usually gives higher pecuniary returns than forests, the cultivation of field crops on felling-areas will generally repay not only the cost of cultivation of the crops and of the forest re-growth, but also yield a surplus. From a pecuniary point of view it would be more profitable to clear all forest areas which are suitable for clover and produce fodder-crops, but the production of wood is the real object of a forest, and attempts to increase the forest revenue must be made within proper limits. The question therefore arises, whether the apparent gain from the field-crops will not disappear when balanced by the consequent loss in productiveness of the soil.

(b) **Stimulation of Forest Growth.**—Combination of field-crops with forest growth necessarily supposes a thorough cultivation of the soil, thus utilizing its nutritive power to the utmost. As on good soil only a portion of this nutritive power is required by the field-crop, and a balance remains over for the use of the forest plants, the usually favourable growth of young forest trees under these circumstances is easily explained. It is no wonder that the reproduction of a wood should succeed on such a loosened soil much better than when nothing is done to the soil, or it is only slightly worked. If without growing field crops the soil were as thoroughly trenched on clear-cut areas or for natural regeneration, the sowing and planting of the forest plants as carefully effected, as fine plants used and the ground weeded as diligently as when field crops are grown, even better sylvicultural results would be attained than in combination with field-crops. As the peasant pays for the cultivation of the ground, the demands on the forest cash-box for the simultaneous or subsequent stocking with forest plants are considerably reduced; to the extent then of supplying a cheap and beneficial mode of cultivating the ground, the admixture of field-crops is an advantage to forests.

2. *Dangers to the Forest.*

The principal danger caused by field-crops to the forest is the consequent reduction in fertility of the soil. The crops take from the soil those very substances which are generally deficient (potash, nitrates and phosphates), and these materials are required just as much by woody plants as by those grown by the farmer, the latter merely requiring them in larger quantities than the former. The agricultural plants, however, grow merely in the surface soil, which owing to the decomposition of the weeds forming the soil-covering and of the humus from dead leaves, &c., and to the cultivation it has received, is more or less richly supplied with assimilable nutritive salts.

The field-crop undoubtedly robs the surface-soil of a considerable amount of nutritive matter, and the more so the longer the land is under crops; the forest plants can satisfy their wants less fully in the soil, the poorer the latter, and the more exacting the species of tree grown, and the less provision has been made for its roots to penetrate deeply in the soil. But when coppice is grown associated with field-crops (*Hackwald*), the greater or less reduction in fertility of the soil occurs every 15—20 years only; or when high forest is so grown (*Röderwald* and *Waldfeldbau*), only every 80—100 years: if then, the soil-covering is carefully protected on areas so treated, no litter removed and the soil by nature sufficiently rich and moist, the results of the deprivation of nutriment will be very little felt. In the case, however, of poor soil exhausted by the field-crops, bad consequences will result for the forest growth, and if this is not at once visible during its youth the wood must undoubtedly suffer in its subsequent development.

Whenever temporary field-crops are to be grown on a sufficiently rich soil with the least possible damage to the forest crop, care must be taken that the young woody plants are rooted in a lower stratum of the soil than that in which the field-crop is grown. This is secured by cultivating the soil deeply, and restocking it with woody plants with deep rather than superficial roots, and with transplants rather than by seed.

From the above considerations it follows that from a sylvicultural point of view field-crops may be grown profitably in combination with forestry only on well-cultivated soils rich in nutritious salts, and that then it is the cheapest and most certain method of restocking a felling-area. On poor soils this system is quite unjustifiable, as has been proved in numerous cases.

Of all the methods which have been tried, the *Waldfeldbau* is the best, because it implies a thorough working of the soil, no loss of wood-increment and clear-felled areas are at once restocked. But even on superior soils field-crops should not be maintained for more than two years.

[In France and Belgium, cleared areas, on which conifers grew, are frequently cultivated for one year with a field-crop, after burning (*sartage*) the soil-covering and refuse from the felling : this reduces danger of damage by insects to the succeeding crop of conifers.

In Burma bamboos and other inferior species prevent the growth of teak, advantage is therefore taken of *jhume* cultivation, which is termed locally **taungya**, to get the area sown with teak-seed, the teak plants growing into forest after the cultivation of field-crops has been abandoned.—Tr.]

CHAPTER IV.

HARVESTING THE FRUITS AND SEEDS OF FOREST TREES.*

The fruits and seeds of forest trees are employed in several ways. They are used for the artificial reproduction of woods and for feeding pigs, &c., also in the preparation of oil and other industrial products.

[Indian forest-fruits, and also dried flowers, besides being similarly employed, are used :—for dyes and tanning (Myrabolans or fruits of species of *Terminalia* and fruits and flowers of many other trees); for making alcohol (flowers of *Bassia latifolia*); for human food (seeds of Bamboos, *Pinus Gerardiana*, *Buchanania latifolia*, flowers and seed of Bassia, &c.); fruits of *Bombax* and *Calatropis* yield fibre for stuffing pillows, and which can sometimes be spun.—TR.]

This chapter will be divided into 4 sections, dealing respectively with the **collection** and **storing** of seed for the **artificial reproduction of forests, pannage,** and the **collection of fruits and seeds for industrial purposes.**

SECTION I.—HARVESTING FRUITS AND SEEDS FOR THE ARTIFICIAL REPRODUCTION OF TREES.

Owing to the extent to which artificial reproduction of forests is now carried, the harvesting and preservation of forest seeds has become an important industry. Formerly every forest owner collected his own seeds, which was quite possible owing to the then limited use of artificial reproduction. Many seed-merchants have now embarked in this business, generally to the great benefit of forestry; their attention has however been chiefly directed to coniferous seeds, whilst the collection and preservation of seeds of broad-leaved trees is still, for the most part, left to forest owners.

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* [In this chapter the botanical distinction between fruit and seed is not always followed.—TR.]

1. *Production of Seed by different Species of Trees.*

A sufficiency of nutritive reserve-material, light and heat are the chief causes of the production of fruit. A fair amount of the annually assimilated material not employed in the construction of new wood, is stored-up in trees, especially in their medullary rays [also in the leaves of evergreen species.—Tr.]. Once this reserve-material has attained a certain amount, the tree can blossom and produce fruit. Nearly all the reserve material in a tree is exhausted during a seed-year, and it then again commences storing a fresh supply. A warm, dry, sunny growing season when the tree produces little wood, is a condition for blossoming in the succeeding year. When once the inflorescence-buds are formed, the weather during the blossoming period will decide matters (absence of frost in the daytime, &c.); in the case of species which require much heat the succeeding summer weather may cause the fruit to ripen, or may not be sufficiently warm for the purpose, and at any rate will affect its comparative abundance or scarcity. For a plentiful seed-year, therefore, **two successive warm years** are required; cold years and especially wet and cold years are never rich seed-years, or produce much useless seed. This rule is not, however, universal, and there is much difference in this respect among different species of trees.

Thus, in the case of beech, a preliminary warm, dry year is more important than the state of the weather in the actual seed year. Once the inflorescence-buds are formed and the spring passes without damage by frost, the beech-mast will ripen, even when the summer is unfavourable (for instance in 1877, 1882, 1888). For the oak, on the contrary, the seed-year must be warm and dry; hence, years of plentiful acorns coincide with a good vintage, whilst beech-mast years follow one. For the oak, therefore, the formation of good inflorescence-buds is readily effected, the open oak forest obtaining more light and heat than dense beech-woods.

The natural period for fruiting is the latter part of the pole-stage and the commencement of maturity, when trees have attained their full height and are growing vigorously in girth. This period is termed **fertility**, and its earlier or later appearance depends on the species, nature of the locality, amount of light received and the individual healthiness of the tree.

Good quality and germinative power of seed is usually associated with vigorous middle-age, and though generally, in the case of many trees, the seed of very old trees (beech), or of very young ones (larch), are either of little value, or the trees altogether lose their fertility when very old (spruce at 130 to 140 years), yet there are several species to which this rule does not apply. Acorns of 300 years old oaks are often as good as those of younger trees, whilst the seed plucked from Scotch pines, 10 to 15, and even 8 years old, is often better than that from older trees. Independently of the species, the nature of the locality affects matters so that poor soils and slow growth hasten fertility, even though seed-production always presupposes a sufficient supply of nutrition in the soil (fine humus), chiefly of phosphoric acid. Above all, the local amount of heat is decisive, trees growing at high altitudes producing only a scanty supply of fruit; at the limit of vegetation of mountain-trees (for instance, the larch), only at the most vigorous period of growth is any fruit produced. Light is also requisite for blossoming, trees growing with expanded crowns fructifying, therefore, earlier and more abundantly than those growing in a dense wood.

Seed may be sufficiently good to germinate, but possessed of so small an amount of reserve-nutriment that it may be unfit to produce vigorous plants.

The productiveness of fruit by German forest trees has considerably diminished of late, and this seriously interferes with the natural reproduction of woods. The cause of this change is chiefly to be ascribed to the even-aged high forest system; for slender, drawn-up, crowded trees tend to produce wood rather than fruit.

The general state of fertility of a woody species, however, depends chiefly on the question whether seed-years are frequent or the reverse. Some trees only fructify after stated intervals, whilst others are irregular in this respect; in some cases several years may pass between successive seed-years, in others, the trees bear fruit every year. The nature of the soil and climate, and the comparative density of the standing crop influence matters, so that sterile periods are shortened by mild climate; in extensive dense mountain-forests they are usually more prolonged than in isolated woods more easily affected by changes in the weather. The species which usually fructify only periodically are: beech, Scotch pine, oak, sweet chestnut and larch; on the other hand, in fairly mild climates, hornbeam, sycamore and other maples, lime, silver-fir, ash, elms, black alder, birch, &c. fructify almost every year.

The beech produces fruit after the longest intervals and with the most marked periodicity. In Germany, an abundant beech seed-year can be expected only every 10 years, sometimes as many as 10—15 years pass without any seed at all.

[In France and Britain, beech seed-years occur more frequently (every 5 or 6 years), except in the Vosges, Jura and Alps, (every 10 to 15 years), but according to Mathieu,* partial seed-years are more frequent in mountainous regions than in lowlands and hills.—Tr.]

In mountains up to moderate altitudes, there is (in Germany) a small production of beech-mast every 3 or 4 years which is not without value for natural reproduction. Two successive abundant beech-mast years are rare events, and then a longer period lapses before another seed-year occurs.

The Scotch pine, spruce, Cembran pine, oaks and sweet chestnut fructify at intervals of 3—5 years. Most of these species produce some fruit every year in lowlands, especially oaks and Scotch pine, provided the weather is at all favourable, but complete crops of seed occur only as stated. Oaks and chestnut trees produce most fruit in years of good vintage. The seed-crops of both spruce and Scotch pine are generally abundant; the fertility of the spruce, however, greatly depends on the altitude at which it is growing, and the consequent climate of its locality. At altitudes over 1,000 meters (3,280 feet) spruce seed-years occur only every 8—10 years. The above-mentioned trees do not, however, possess the same marked periodicity in seed-bearing as the beech.

Under favourable circumstances, hornbeam, birch, sycamore and maples, elms, alder, larch, silver-fir and lime fructify almost every year. The hornbeam frequently fructifies successively for three or four years, and always in abundance. So with the birch, whilst the larch and silver-fir fructify almost every year, it being rare for 3 years to pass without silver-fir seed. At the same time these two conifers are more frequently sterile for one or two years than the above-mentioned broad-leaved species. Different species vary in the **abundance of seed produced in a seed-year.** Beech, elms, Scotch pine and spruce are the most fruitful; birch, hornbeam, oaks, sycamore and other maples, alder, silver-fir, Cembran pine produce a moderate amount of seed, whilst ash and larch produce seed scantily.

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* *Flore Forestière*; Berger Levrault et Cie., Nancy, 1877.

The **quality** of the seed depends less on the species of tree and the locality than on the state of the weather and age of the trees. The fruits which fall earliest, and cones of old trees (spruce for instance) are generally sterile.

2. *Season of Maturity and Fall of Seed.*

Most seeds ripen earlier or later in the autumn, according to the nature of the locality and the state of the weather during summer. Fruit usually ripens on north and east aspects later than on warmer ones; dry localities and hot summers expedite maturity, but frequently not to the advantage of the seed harvest, as there are then more sterile seeds than under opposite conditions and insects do greater damage.

Acorns usually ripen at the end of September, and fall from the trees with the first frost, usually about the beginning of October. Sessile oaks ripen their acorns somewhat later than pedunculate oaks [and should be collected separately owing to the great sylvicultural differences between the trees.—Tr.]. The sterile and grub-eaten acorns which fall first soon decay if the weather is at all damp, turn black, and may be easily recognized and rejected. It is therefore customary to collect acorns only from the end of October. **Sweet chestnuts** ripen with grapes in October and fall as soon as they are ripe. They ripen freely in the South of England after hot summers.—Tr.] **Beech-nuts** also ripen in October and they usually fall at the end of October, or the beginning of November; exceptionally, and especially in damp weather, they may remain unopened on the trees and fall during dry east winds in December and January, frequently on to the snow. **Hornbeam-nuts** ripen in October, but usually remain hanging on the trees till the end of winter, especially on large trees in damp localities. **Birch-Catkins** often ripen in June, but in July and August when the weather is unfavourable; their dissemination is also irregular, being at the end of July when the catkins ripen early and the weather is favourable, otherwise, during autumn; not unfrequently they are still hanging on the trees in November. If the catkins come to pieces when handled it is a sign that the seed is ripe. Few trees produce more sterile seed than the birch, and birch-seed may be considered good if 30—40 % of it will germinate. **Alder-Catkins** ripen at the end of September or early in October; the seed rarely falls before the end of November, but usually the closed catkins remain hanging on the trees through the winter, and open and shed the seeds only in February and March. The middle catkin scales open first and contain the best seed. **Elm samaras** ripen by the end of May or the beginning of June, and are disseminated very soon after ripening.

[Seeds of the wych-elm should be kept separate from those of the common elm. They are readily distinguished from one another by the seed being in the *middle* of the samara of the *mountain* or wych-elm.—Tr.]

Elm-seed ripens irregularly, green samaras being on the trees after much seed has fallen. Only the samaras which ripen late are fertile, those falling early being all sterile. From 30 to 50 % of elm-seed is bad. **Ash-samaras** ripen in October, and usually hang on the trees through the winter, falling during dry weather in February and March. The fruit of the mountain-ash (*Pyrus Aucuparia*) ripens in September, and frequently remains for a long time on the trees. **Samaras of the sycamore** and other indigenous maples usually ripen in September and October, falling a few weeks after maturity; occasionally, especially in the case of sycamore, the fruits remain hanging on the trees in winter and fall on the snow. **Lime** ripens its fruit at the end of October, the latter falling with the peduncles attached to it late in the autumn and during winter. Much lime-seed lying on the ground in October is sterile. **Spruce-cones** ripen at the beginning of October, but the seed, as a rule, only falls in the spring during the prevalence of dry winds. Nobbe states that the greenish coloured cones of the so-called *white spruce* yield better seed than the reddish-brown cones of the *red spruce*. **Silver-fir cones** ripen in September or the beginning of October, and the seeds fall forthwith. The opening of the topmost scales of the cones is a sign of impending seed-fall. **Larch-cones** ripen in October, remaining closed till the spring and opening very gradually; the seeds are disseminated very irregularly and over a long period. Cones of the **Scotch, black, maritime** and **Cembran pines** ripen at the end of October during their second year on the trees. They remain closed on the trees till March or April of the third year. **Cones of the Weymouth-pine** also ripen in the autumn of the second year, but frequently open late in the autumn of that year.

3. *Methods of Collecting Seed.*

Seed should evidently be collected only when perfectly ripe, for seed gathered when unripe never germinates well and loses the power of germination much sooner than fully ripe seed. The urgency of the collection of the seed depends on whether it falls as soon as it is ripe, or remains hanging on the tree for some time after this event. Thus, for instance, the seed of silver-fir, sycamore and other maples, elms, birch, Weymouth-pine, &c., should be collected as soon as it is ripe (Silver-fir cones are even gathered shortly before ripening), whilst pine-cones, alder catkins and ash-samaras may be gathered at any time during winter, the best months for harvesting larch-seed being March and April. Scotch pine and larch cones which have remained closed during the winter are much more easily opened if collected only in the spring. Whilst for these species there is no danger of the cones opening and the seed becoming scattered before dry spring weather has set in, this danger may be feared for spruce cones, which open much more readily, and their timely collection is therefore advisable. It is obvious that no seed should be collected until the sterile and grub-eaten fruits have fallen and have been eaten, if possible, by pigs or sheep. This is especially to be noted for beech-mast, acorns and the seeds of birch and elms.

Although it is desirable that many fruits should be collected in dry weather, in order that they may be stored dry and be thus better preserved from decay, this is not always possible. In the case of resinous cones it is not even necessary; but moist fruits containing much starch, such as acorns, chestnuts, &c., should be collected dry.

The **mode of harvesting** varies for different fruits, the following methods being employed: climbing the trees and plucking or stripping-off the fruit, for sycamore and other maples, elms, hornbeam, ash, alder, and all the conifers; collecting the fallen fruit from the ground, for oak, beech and chestnuts; collecting it from felled trees for all conifers but silver-fir; finally, collecting alder-seed from the surface of water.

(a) **Climbing Trees and Plucking the Fruit.**—Collectors climb trees by the help of ladders or climbing-irons (see fig. 124*a*, p. 238), with a bag over their shoulders, and either pluck whatever fruit they can reach, or strip the fruit-bearing branches by passing them through the hand. Although this is an expensive method, yet it is employed for birch, sycamore and other maples, elms, hornbeam and to some extent for ash. The fruits of these trees are small, mostly provided with wings, and are liable to be blown far from the tree, so that collecting them from the ground, except on a smooth road, is impracticable. This may, however, be done if the twigs which bear the fruits are cut from below by means of pruning-shears on a pole. Even the fruit-bearing branchlets may be thus lopped, if the trees are shortly to be felled.

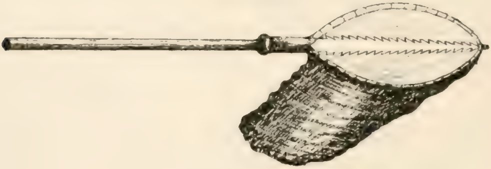
Cones are gathered by a collector, who mounts the tree with climbing-irons and cuts off the cones by means of a sharp hook at the end of a stick. The cones are then gathered into sacks from off the ground. It is more troublesome and dangerous to collect silver-fir cones in this way (as they are at the very top of the tree) than those of spruce or pines. In the case of the Scotch pine, owing to the brittleness of the branches, much young wood may be thus destroyed; this should be avoided if possible, for the male and female inflorescence are on different branches in this species, and to break the twigs with the cones attached hinders the formation of female inflorescence and prevents the formation of cones for future years.

[In India, mangos are gathered from trees by means of a purse-net on a long bamboo, as shewn in fig. 279; the saw cutting through the twig which supports the fruit.—Tr.]

It is often advisable to climb alder trees and pluck the fruit-bearing branches, if certain parts of the crowns are laden with ripe catkins as is often the case with trees bordering a wood.

(b) **Collecting Fruits and Seeds which have been shed by the Trees.**—Only large fruits and seeds such as those of oaks, chestnut and beech can be collected from off the ground, as they can be easily picked up by hand. The seeds are then thoroughly ripe, a fact important for their preservation. Those which fall first should be abandoned as sterile and wormeaten. It is better and cheaper to employ women and children for the work than men, and they should hunt among the leaves for the fruits and place them in sacks. The work is facilitated if the dead leaves, &c. are brushed away from under the trees before the fruit has fallen; the latter is then swept into heaps and shaken in a coarse sieve, which will remove the dirt. This may be done provided the litter is replaced after the seed has been collected: this precaution is, however, frequently neglected, and the soil under the trees thus impoverished. On this account, sweeping the seeds together should be avoided, except on naturally cleared spaces, roads, &c., where frequently the shed fruit of elms, sycamore and ash may be thus collected.

Fig. 279.



(After Fernandez.)

If the season for the natural fall of the fruit or shedding of the seed is at hand, this may be effected artificially by shaking the fruit-bearing branches [on to a cloth spread on the ground or held under the tree.—Tr.], a method used in collecting hornbeam or ash seed, and especially for beech-nuts. In the latter case, the stems of the trees are sometimes struck with axe-heads; this should never be done to young trees, and though not hurtful to old trees ripe for the axe, is not then very effective.

(c) **Gathering Fruits from Felled Trees.**—This can obviously be effected only on felling-areas, in the case of winter-felled trees. It is possible only for trees the ripe fruit of which remains hanging on the trees during winter, such as Scotch pine, spruce, larch, and sometimes alder and ash. According to the extent of the felling-areas, a large quantity of fruit may often be thus harvested in the cheapest possible manner.

(d) **Collecting Seeds from the Surface of Stagnant Water.**—This is done only for seed of the common alder. Alder trees growing on the banks of lakes and ponds, which usually produce abundance of fruit, shed most of their seed into the water, where it is blown by the wind into the still water of bays and inlets and may be artificially collected by placing fascines at the outlet of the sheet of water. The floating seed collects in masses in front of the fascines and may be easily collected in linen purse-nets. It must then be carefully dried.

(e) **Cost of Harvesting the Seed.**—The forest owner may, in various ways, either harvest the seed for his own use or sell the crop. In the former case, he may collect it by daily labour or piece-work; he may give the crop to a dealer on condition of receiving a sufficient supply for his own requirements, or lease the whole crop.

It is only seeds of subordinate species of trees used in mixed woods that are collected by daily labour, for it is then rare that seed is required in large quantities. This is the case, for instance, with sycamore and other maples, ash, elm, hornbeam, and lime, and to a certain extent with birch. It is always better to collect seed by piece-work and pay according to the quantity collected. Whenever it is desirable to collect the whole available crop of seed in a wood, the rate paid per pound must naturally be proportional to the ordinary daily wage for other similar work. This is especially the case in the collection of cones, when the work may also be in progress in neighbouring forests and if sufficient payment is not made for the seed, much of it may find its way into the hands of seed-merchants or neighbouring forest owners. In the case of fruits which may be used for other purposes besides the artificial reproduction of woods, especially acorns, beech-nuts and chestnuts, even slightly more than the full value of the fruit must be paid; otherwise the forest owner will secure only a very small portion of the crop, in spite of the most careful supervision.

Surrendering the whole crop of seed to the neighbouring peasants on condition of receiving a stipulated portion is the commonest mode of harvesting acorns and beech-nuts. This method is evidently applicable only when the fruit is used for other purposes besides artificial reproduction. It is carried out by giving formal permits to applicants allowing them access to the forest to collect acorns or beech-nuts, on condition, that they deliver a small percentage to the forest owner. Finally, when the owner does not need the seed for his own requirements, he may lease the whole crop to seed-dealers.

4. *Treatment of Seed after Collection.*

The fruits and seeds which have been collected in the forest are often extremely moist, they must then be dried or will turn black, decompose and lose their germinative power. They should, therefore, be brought into dry, airy places, spread out in thin layers and turned three or four times a day. In dry weather the larger fruits are dried in a preliminary manner in a suitable place in the forest; they are then brought under a roof and spread on a wooden floor. The fruit or seeds of broad-leaved trees should be dried sufficiently but without being hardened, and the husks, twigs and other refuse removed as far as this can be done by simple manipulation; they are then ready for storing.

Twigs, with the attached samaras of sycamore, other maples and elms, birch-catkins, &c. are hung up to dry in airy lofts or sheds. As soon as they are dry the fruits fall from the twigs and may be swept into heaps; they may then be placed in sacks, and in the case of birch-catkins, shaken and pressed until the catkins are broken up. Great care must be taken with birch seed from the first, for it easily turns mouldy; it should be spread out in thin layers and frequently turned. Elm-seed is also very liable to become mouldy; in order to avoid the trouble of storage, it is frequently sown in June as soon as it is ripe. Berries of the mountain-ash are completely dried and sown with their shrivelled skin; or they may be macerated in water, and the skin washed off the seed. Alder-catkins collected in November and December are placed in moderately hot rooms in order to open the catkins and allow the seed to fall; the seed is then separated from the catkin-scales by sifting.

According to Burckhardt* the weights of air-dried seed of the different broad-leaved species of trees are as follows:

Name of seed.	Per hectolitre. Kilograms.	Per gallon. lbs.
Acorns	75	$7\frac{1}{2}$
Hornbeam (without wings)	50	5
Beech-nuts	45	$4\frac{1}{2}$
Alder (clean seed)	30	3
Ash	15	$1\frac{1}{2}$
Sycamore (winged)	14	$1\frac{2}{5}$
Birch (according to number of scales)	8—10	$\frac{4}{5}$—1
Elm	5·5	$\frac{1}{2}$

The method of treating cones in order to extract and clean coniferous seeds will be described in the 5th chapter of Part III. of this book.

SECTION II.—STORING THE SEEDS OF FOREST TREES.

1. *General Account.*

Sylviculture shows that it is often advantageous to delay sowing seed until the spring of the year after it has ripened. Seed must therefore be stored for this purpose, and if this can be done without seriously impairing its germinative power, the forester becomes to a certain extent independent of the occurrence of seed-years.

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* Säen und Pflanzen.

Germination depends on the admission of a certain amount of heat, oxygen and moisture to the seed. In storing fruits and seeds it is necessary to preserve the germinative power so that the seed will not germinate during winter; hence the state of suspended vitality in the seed must be prolonged, while the germinative power is fully preserved. All fruits and seeds, however, under similar conditions do not retain their germinative power for the same length of time. In general, seeds with an embryo or albumen rich in starch do not preserve their germinative power so well as those which contain much oil or turpentine. For under their closed husks, provided water is excluded, oxidation of oil is much slower than conversion of starch into gum, dextrin and sugar.

Germinative power is quickly lost in acorns,* chestnuts and beech-nuts, so that these fruits very rarely can be kept for more than one winter. The same rule applies to seeds of birch, elms, silver-fir and alder, which soon become mouldy unless very carefully stored. Seed of ash, hornbeam, lime and Cembran pine, most of which germinates only in the second spring, can be easily stored. [In the case of Weymouth-pine also, much seed does not germinate till the second spring.—Tr.]. Lime-seed can be kept good for 2 or 3 years, but owing to the abundance of seed produced almost every year there is no necessity to store it. Germinative power is longest preserved in the seed of larch, Scotch pine and spruce, and experience has shown that if carefully stored, larch-seed may preserve its germinative power 2—3 years; Scotch pine seed 3—4 years, and spruce-seed 4—6 years.

Over-heating is the chief danger in storing seed, as when kept in heaps with even the very moderate amount of moisture which is always present, the seed becomes easily heated. If, however, seed is over-dried, it loses much germinative power, which is certainly not desirable; over-dried seed when sown germinates very slowly and frequently rots in the ground, seedlings also which have sprung from it may not be sufficiently lignified to withstand autumn-frosts. **Air-dried fruits and seeds** must therefore be loosely stored so as to admit of **moderate ventilation**, and over-heating be thus prevented.

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* More quickly in sessile than pedunculate acorns.

Local climate has considerable influence on the preservation of seed, as is the case in southern districts of Austria. There, in warm winters, acorns sometimes germinate in the pits in which they are stored and become quite rotten by the spring; when, however, they are kept in dry sheds, the dry air of these districts often renders them as hard as a stone, and they lose all germinative power.

The choice of sheds or suitable places in the forest for storing seeds depends on the nature of the latter. Whilst beech-nuts and pedunculate acorns may be dried in the forest if spread out thinly, this cannot be done for acorns of the sessile oak, which become over-heated and germinate very readily. As a rule, it is better to dry seeds under a roof than in the open. Ventilation must not, however, be sufficient to over-harden the seeds so that the kernel separates from the husk. According to experiments made by Braun, fresh acorns when dried as hard as a bone lose 40 % of their weight; when air-dried, as in airy lofts, 20 %; and in the latter case, 2 % of their volume.

The following are the usual methods of storing seeds.

2. *Storing in heaps in the Open Air.*

This method is applicable to beech-nuts, acorns, and chest-nuts. A dry site near a forester's house, with loose, sandy soil for choice, is completely cleared of all vegetable matter, and the fruits are then mixed with plenty of sand and placed in heaps on the ground. The more delicate the fruit, the lower the heaps. The heaps are then covered with dead leaves or straw, at first only moderately thick, and some bundles of straw are stuck through the covering to afford ventilation. As the weather becomes colder earth may be thrown on the covering, but it should always be remembered that seeds are less sensitive to cold than to heat. At the close of winter the covering should be gradually removed in the same way as it was supplied.

It is extremely probable that the destruction of seeds kept over winter is often due to delay in removing their covering.

In the case of delicate fruits which when kept in heaps easily become over-heated, the heaps should be only 4 inches high; they are then made longer and broader than before, or several of them are placed side by side. It often affords sufficient protection against frost to cover acorns or beech-nuts with dead leaves or straw: in localities where the climate is mild, this is the best mode of storing them, the leaves protecting the seed from extremes of heat and cold, and allowing sufficient ventilation without danger of over-drying. Partially dried sand is much better for mixing with seed than flax-refuse, moss, chaff, &c., but sufficient sand should be mixed to keep every seed apart from the rest. It is not sufficient to have alternate layers of sand and seed. In the case of beech-nuts, the sand should be slightly moist, as the nuts are easily over-dried, which condition may be recognized by their comparative light colour.

If the heaps of seed are placed under the dense shade of a spruce, or other tree, it is better in the case of beech-nuts, to cover the heaps with planks rather than earth. Acorns which have germinated in winter may still be sown, as the broken radicle recovers; but in such cases greater care must be taken against over-drying than with ungerminated acorns.

In order to protect the heaps against moisture and mice they are surrounded by a sufficiently deep trench.

[Boppe recommends sprinkling the heap with red-lead, as a protection against mice. When the seed is stirred the red-lead will become pretty evenly mixed throughout the heap.—Tr.]

3. *Storing in Trenches.*

Acorns, beech-nuts, chestnuts and the fruits of ash and hornbeam may be stored in trenches in the open air. The trenches for acorns should be about half a meter (1½ feet) deep, with vertical walls and in long rows; beech-nuts are placed in wider, but shallow, trenches not deeper than 30 centimeters (1 foot); ash, hornbeam and sycamore seed in narrow trenches like drills; the latter should remain for two winters in the trenches, and only be sown in the second spring. When there is only a small quantity of slowly germinating seed, such as nuts of the black walnut, it may be mixed with sand in earthenware pots, which are placed in the ground. It has also proved useful to mix ashes with sycamore, ash and other seed in a cask placed in a dry, well-ventilated locality.

Seed-trenches should be dug in dry, well-ventilated places, secure from drainage-water, and a layer of sand should be placed at their base. The seeds should then be put in, well mixed with sand (not in alternating layers with it) till the trench is full, two bundles of straw inserted to secure ventilation, and the trench covered with earth. Pedunculate acorns may thus be kept over winter in good condition, but the method is less suitable for sessile acorns.

4. *Storing on Banks under Thatch.*

In this method after the seed has been fairly dried, it is placed on long banks raised about 8 inches or a foot (20—30 centimeters) above the ground under a light thatch of straw or dead leaves. Or a flat place may be slightly excavated in the ground and covered by a thatched roof high enough to allow a man to inspect the seed. The seed can then be turned, and its covering modified according to changes of temperature, which is a great advantage.

This method is applicable to acorns of both species of oak and beech-nuts, the seed being mixed with sand as before. By altering the thickness of the thatch and turning the acorns, they are protected against frost and over-heating. Beech-nuts require a cool, damp place, and the ground should be watered for them during very dry weather: they are fairly hardy against frost, and well-ventilated places suit them, which may be paved with stones. When thus kept, however, they must be regularly turned and watered.

5. *Storing in Rooms.*

Sacks of acorns and chestnuts may be kept in cellars, only when the latter are sufficiently dry and well ventilated.

Several other kinds of seed such as that of silver-fir may be kept in rooms. In a room free from frost, or at any rate, from low degrees of temperature, silver-fir seed mixed with the scales of the cones may be placed on shelves, either alone, or with saw-dust. The windows must at first be kept open in order to dry the seed, and the latter turned from time to time. This is absolutely necessary for silver-fir seed, which is very liable to become mouldy. It is best kept in the cones, but they can only with great difficulty be kept entire through the winter.

At Hubertushöhe, in the Franconian forest, silver-fir seed is kept in a wooden tower with several floors, and well-ventilated. The seed placed in thin layers on the floors is turned daily, and keeps splendidly. Silver-fir seed frequently suffers during transport; bags of it should always be loosely closed, and the seed in them mixed with refuse wings of the seed of pine or spruce.

Dried seed of the birch or alder may be placed in sacks and these suspended in dry rooms. If twigs have been cut with the fruit they may be tied in small bundles and suspended as before. Ash, maple, and hornbeam seed may be similarly treated during the first winter before being put into trenches to hasten germination.

Much birch and alder seed, however carefully treated, will become mouldy; it is generally better to sow these seeds as soon as they ripen.

6. *Storing in Perforated Bins.*

Scotch pine, spruce and larch seed separated from the cones is best preserved in perforated bins; the same plan is suitable for any small seeds after they have been thoroughly aërated by turning them over for several days.

The bins used for coniferous seeds resemble ordinary flour-bins, with well-fitting lids. In order to exclude mice they are completely lined with tin or zinc, which is perforated as well as its wooden casing. The seeds are placed in the bins with their wings and other impurities, and are periodically stirred. Spruce seed is sometimes kept in the cones.

7. *Storing Seed under Water.*

Experiments have often been made of storing beech-nuts and acorns in large baskets under water, but although they remain perfectly sound in water, a large proportion of them usually rots after the seed has been sown. This method may, however, be adopted for acorns stored for feeding game. Alder seed taken out of ponds, &c., also keeps very badly in the winter.

SECTION III.—PANNAGE.

1. *General Account.*

Acorns and beech-nuts are the chief forest fruits used for feeding swine or deer, which also eat chestnuts, hazel-nuts, blackberries, &c. This kind of fodder is collectively termed **mast**, a word connected with the German *mästung* (fattening); it is chiefly utilized by driving swine into the forest to feed, and the usage is termed **pannage**.[*] Less frequently, mast is collected and used to feed pigs or deer. [Thus, near Windsor Forest, one shilling a bushel is paid by farmers for acorns collected in October by women and children.—TR.]

In earlier times, pannage in the then extensive oak and beech forests of Europe, was, next to hunting, the chief forest usage. [Very prevalent in English forests from Saxon times.—TR.] The records of pannage in Germany date from the 12th century.[†] Later on, the people living near forests divided the pannage among their numerous herds of swine, and, especially in the 16th and 17th centuries, rearing swine had attained great importance in most forest districts, and produced considerable wealth. Pannage is still extensively followed in Servia, Hungary, Galicia and other countries.[‡]

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[*] Baden-Powell states that pannage is derived from a middle-latin word *pannagium*, feeding swine on fallen acorns, said to be further derived from *pastum*, feeding. The double *n* marks some contraction, as if it were *pastinagium*; this is somewhat confirmed by the old French word "*pasnage*," payment to a landlord for the right of feeding swine.—TR.

[†] The abbot of Mauermünster issued a forest regulation in 1158, in which misappropriation of acorns was considered a forest offence.

[‡] [In Britain, pannage is chiefly exercised in the New Forest, where, according to the Deputy Surveyor, in an ordinary good mast-year, about 5,000 swine are admitted. The numbers in the last five years were

1890	4204	1893	486
1891	684	1894	1235
1892	1030		

The small number in 1890, the last good mast-year was owing to the prevalence of swine-fever. In Epping Forest, only about 50 swine are admitted annually and a few in the Forest of Dean, being ringed in both forests.—TR]

In Germany, although a certain reverence for antiquity preserved many old oaks up to the present century, pannage had lost much of its former importance even in the 18th century. This was owing to the increasing value of timber, the prolonged bad treatment of forests by over-felling and pasture, and the fact that a large part of the broad-leaved woods had disappeared. Its disuse was also hastened by the increasing cultivation of potatoes, which offered the peasant, independently of the forest, a cheap means of fattening his pigs. However, by stall-feeding, the firm fat pork due to pannage is no longer produced, and in rich mast-years the larger tracts of broad-leaved forest are still in great demand for fattening pigs.

2. *Different Kinds and Qualities of Mast.*

Pannage pre-supposes mature beech- and oak-woods, and can obviously be utilized only in seed-years. In sterile years, pigs may obtain enough food in forests to keep them alive; their fodder is then termed **ground-mast**,* and comprises worms, larvæ and pupæ of insects, fungi, mice, &c., which sometimes afford them sufficient food. **Mast proper** † consists of acorns, beechnuts, wild fruits and hazel-nuts.

The quality of mast varies considerably with the year, locality, age of the trees, whether they are grown in dense woods or isolated (as over coppice or in high forest); in the latter an acre produces a much heavier crop of mast than in the former. Other factors also intervene, and there is generally less oak-mast than beech-mast, but the former is of better quality. Formerly, owing to the number of trees with large crowns fully exposed to the light, the quality of mast was better than at present. The superior quality of acorns to beech-mast is due to the fact, that the latter is heating to the animals, which require to be watered more frequently than when fed on oak-mast. Beech contains much oil, as well as starch, and this is more adapted to fatten swine than to form flesh. Hence, beech-mast produces as fat pigs as oak-mast, but their flesh is softer and not so firm and marbled as when they are fed on acorns.

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* In German, *Untermast*, *Erdmast* or *Wuhl*.

† In German, *Obermast* or *Eckerich*.

When pigs are fed on both oak and beech-mast, they always prefer the former, they also prefer pedunculate to sessile acorns. Frequently after eating acorns only hunger will make them eat beech-nuts, and there is then always an interval during which the swine fall off in condition. This is due to the angular shape of the beech-nuts, which hurts the pigs' mouths, as is shown by the fact that they always prefer beech-nuts which have been some time on the ground and are softer than freshly-fallen ones.

Ground-mast is always a useful adjunct, not only on account of its amount, which varies according to locality and depends on the state of the foregoing summer-weather, but also because of its influence on the health of the pigs. Larvæ of insects, worms, fungi, &c., contain much more nitrogenous matter than beech-nuts and acorns; ground-mast, therefore, not only assists in fattening the animals, but also affords a variety of food.

3. *Quantity of Mast.*

The quantity of mast in any season is distinguished as **full-mast** (*volle-mast*), **half-mast** (*halbe* or *Fall-mast*), and **quarter-mast** (*Viertel* or *Vogel-mast*). **Full-mast** is when the oaks and beech-trees are so laden with fruit that there is sufficient not only for natural regeneration purposes, but also a large superfluity for swine. In the case of **half-mast**, only a few pigs can be fed. In **quarter-mast**, only individual trees bear fruit, and, as there is not sufficient for complete natural regeneration, pigs must be excluded.

The quantity of mast in any district depends on the comparative frequency of seed-years. It is certain that in Germany they were formerly more frequent than at present. Towards the end of last century, three mast-years in every six or eight years might be safely anticipated—namely, one half or full-mast, and two quarter-masts. Full beech-mast years were, even then, rare occurrences. At present, only one full beech-mast and two or three quarter-masts may be reckoned on every 12 to 15 years. In many districts, during 10 years there may be only quarter-masts. In many places, however, there is some oak-mast nearly every year, but, as a rule, an oak-mast occurs only every two or three years.

This falling off in the number of mast-years is due to the present condition of woodlands. The numerous broad-crowned oaks of former years have become rare, the rotation of beech-forests has been shortened and woods are now grown more densely; many a coppice-with-standards has also been converted into a dense high-forest, and hence the conditions for an abundant production of fruit have disappeared.

4. *Time and Duration of Pannage.*

Acorns and beech-nuts fall about the end of September and the beginning of October, the former somewhat earlier of the two. During wet autumns, when the beech-husks remain longer closed, the beech-nuts frequently remain on the trees till winter. The period for the admission of swine into a forest depends on the quantity of available mast: if they enter the forest before sufficient mast has fallen, they get out of condition from wandering about in search of food and the swineherds cannot keep them in hand.

The most usual period for the commencement of pannage is from the 15th to the 20th of October; it lasts until the middle or end of January, according to the state of the weather. This period is divided into two parts, **early** and **late mast**. The latter is inadequate for fattening pigs but is useful for feeding brood-swine. When mast commences, it is often usual, and in some districts supported by legal enactments, for the pasture of cattle and sheep to stop. In many places this cessation of pasture occurs from St. Bartholomew's Day (the 24th of August); in others, not until the mast has fallen.

5. *Sylvicultural Limitations to Pannage.*

The following limitations to pannage are advisable on sylvicultural grounds:—Closure of all places where swine will damage natural regeneration; limitation of the numbers of swine in proportion to the amount of mast available; finally, admission of the swine only in regular herds under the control of responsible herdsmen. It should always be remembered that only the superfluity of mast, beyond the actual requirements of the forest, is available for pannage.

(a) **Extent of Possible Advantage of Pannage to Forests.**—Belief in the cultural advantages of pannage requires limitation; in many cases more harm than good to the forest results; the standing crop may suffer by breakage of young growth, or by the mast being eaten in natural regeneration-areas, or by exposure of roots on shallow soil, where the pigs often loiter about. Only in extensive Scotch pine forests, where the herds of swine feed on the pupæ of the pine-moth and other insects, and destroy quantities of mice, can pannage be considered wholly beneficial.

All woods, when damage is to be feared, must be closed to pannage. Exceptions are:—the temporary passage of a herd of swine through a wood richly supplied with mast, if they are admitted early in the morning when hungry, feed chiefly on acorns, beech-mast and other fruits, and effect little breakage; seeding-fellings before any young plants have appeared, but it should then be noted that the partial breaking-up of the soil by the pigs is not nearly so useful as uniform cultivation with the hoe; also if only a little of the mast is required for natural regeneration, swine may be admitted temporarily in the afternoon, after they have, to some extent, satisfied their hunger.

Similar precautions (as regards the admission of swine) must be taken in forest compartments reserved for feeding game.

Ground-mast should be utilized only in parts of a forest where there is a real advantage in having the soil broken-up. This is the case in damp soils, or in places where it is wished to tread in the dead leaves and prevent their being washed or blown away. Pannage is decidedly hurtful when swine are kept throughout the year in a forest either on level ground or on hill-sides, and on poor, shallow or sandy soil which thus becomes still more deteriorated.

(b) **Limitation of numbers of Swine.**—Sylviculture demands that only a suitable number of swine should be admitted to a forest, for the herds can be kept under control only as long as there is sufficient mast for their food. If the mast is insufficient, the swine wander over a larger area in order to satisfy their hunger; they then break into the adjoining closed portions of the forest, and can be kept in hand only with difficulty. It is therefore absolutely necessary to estimate the quantity of mast in a forest, and to fix the number of admissible swine accordingly.

In estimating a crop of mast, the following points should be considered: extent of the area stocked with mast-trees, density of the wood, nature of the soil, whether there are many oaks or not, amount of mast produced that season, quantity of ground-mast, &c. Although all these factors should be brought into the reckoning, it is safer to base the valuation chiefly on the experience of former years. Unless the number of swine admissible is regulated by custom, or fixed by legal enactment, averages may be taken of the number admitted in previous years, either of full or half mast. If, then, any changes which have occurred in the woods and the comparative richness of the actual crop of mast are considered (the practical advice of peasants and swine-herds being taken), the forester may form a sufficiently accurate estimate of the number of swine admissible. He need not fear that the peasants or swineherds will over-estimate this number, for to do so is clearly against their interests; swine which are only half fed in the forest come home hungry, and require stall-feeding, and the swineherd has ten times the trouble in such cases, especially at night, when he cannot keep the herd together.

(c) **The Swine must be kept in Herds, under Trustworthy Herdsmen.**—It is clear from what has preceded that much responsibility devolves on the swineherds, both as regards the proper feeding of the pigs, and their control from a sylvicultural point of view.

The swineherds must not only keep the pigs together and prevent them from entering closed portions of the forest, but carefully control the pannage. The most important points for their attention are:—careful choice of feeding grounds, which should be changed from time to time, according to nature of locality; state of the weather; distance from the night-resorts; moderate use of wallowing-places, according to the state of the weather and the amount of moisture in the soil; above all, attention to all matters which assist in keeping the herd healthy and well fed. As a rule, the interests of the forest owner and of the owners of the pigs do not clash.

6. *Revenue from Pannage.*

In the majority of cases where pannage is exercised, the swine owners have prescriptive rights to the usage. The right is usually so worded that a fixed number of swine are admissible into certain parts of the forest, either to early or late mast, or throughout the mast period. Wherever no prescriptive rights exist, and the forest owner is willing to allow pannage, it is usually leased or a bargain made with the swine owners.

SECTION IV.—INDUSTRIAL USES OF FOREST FRUITS.

Besides the uses of forest fruits for artificial reproduction of woods and for pannage, many kinds of fruit are also used in other industries. The chief of these is oil-pressing, principally from beech-nuts, but also from those of hazel and lime.

Beech-nuts, when pressed for oil, should be thoroughly ripe, and not have been too long on the ground. They are picked up by hand from the ground, best in October, as soon as possible after they have fallen. [In France,* the nuts are also swept-up and sifted, the ground being cleared, before they fall, of underwood and dead leaves, which are replaced after the nuts have been collected.—TR.] The quantity of oil the nuts contain varies in different years; in dry years they yield more oil, but there are also more bad nuts than in moist years.

The beech-nuts are dried indoors on dry, well-ventilated floors. Too quick drying, owing to the nuts being taken indoors too soon, always injures the quality of the oil which then becomes slightly rancid; when, however, the beech-nuts have been properly air-dried, they may be completely dried by means of a stove. The bad nuts are then removed, as they are also very prejudicial to the quality of the oil. If it is intended to produce oil of the best quality, the dried beech-nuts should be peeled. The removal of the hard testa from the nuts is advisable, not only to improve the quality of the oil, but also to increase its quantity as the results given below will show. It can be best effected by threshing the stove-dried nuts and winnowing them, so as to remove the chaff. The nuts are then pressed in an oil-mill, and they should be cold-pressed in order to preserve the flavour of the oil.

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* This usage was formerly extensively pursued in France, but was prohibited by the Ordonnance of 1669, on the ground that the nuts were required for natural forest reproduction. This law was abolished in 1794, and the State Forests opened free of charge for the collection of beech-nuts. The French forest code of 1827 again prohibited the practice, but allowed the French Forest Department to authorise it, in certain cases, where the seed was not required for regeneration, on payment of small sums. Thus in the forest of Retz, near Soissons, 32,400 acres, the beech-nuts in 1869 sold for £600, being collected by 4,354 people. 60,000 bushels were collected (100 bushels per acre of seedbearing wood) and the oil pressed from the nuts was worth £17,600. Vide *Rev. des Eaux et Forêts* 1872, also do. 1893.

The quantity of beech-oil produced is very variable—according to the season, the more or less careful removal of impurities and bad nuts, the amount of pressure they have received and whether or not they have been peeled. Pressing beech-nuts for oil pays the forest owner better than leasing the pannage. According to Ihrig, the yield of an acre of mature, densely-stocked beech high forest in a good mast-year, is about 18 bushels of cleanly sifted and dried beech-nuts, worth £2 and more.*

Bechstein states that 1 cwt. of dry beech-nuts yields 8 lbs. of oil. In experiments made in 1843 (in a dry year), 5·2 lbs. of dry beech-nuts gave 1 lb. of oil, about 19·2 %. Kissling states that 120 lbs. of dried beech-nuts gave 85 lbs. of kernels, and these yielded 19 lbs. of oil, whilst 120 lbs. of unpeeled nuts only gave 13 lbs. of oil.

R. Wagner's experiments gave the following results :—

Kind of Nuts.	Year.	Percentage of Oil.
Beech	1857	23·3
,,	1858	25
,,	1859	18 to 22·6
Hazel (peeled)	1858	50
,,	1859	52 to 54
Lime		30·2 to 41·7
Cembran-pine (unpeeled)		29·2
,, (peeled)		36·5

It may be mentioned that beech-nuts have been used as a substitute for coffee, and fruits of different species of *Pyrus* and *Sorbus*, and wild cherries, for the distillation of alcohol. Edible chestnuts are also a valuable article of minor produce wherever the climate will allow the fruit to ripen and attain the flavour they possess in vine-districts of the Rhine valley and in southern Europe. [The larger kinds of chestnuts exported from Spain and other South European countries are from cultivated fruit-trees which are grafted on to wild stocks. Sweet chestnut trees are now found on the lower hills of the N. W. Himalayas, where they have been introduced from Europe and their fruit is regularly sold in some of the Indian bazaars. It is doubtful whether the grafted variety of chestnut has yet been introduced into India.—Tr.]

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* Fortier states that in the forest of Retz, an acre of beechwood 150 years old with 70 trees per acre yielded in 1867, 55 bushels an acre, and in a wood 85 years old, half that quantity. *Rev. des Eaux et Forêts*, 1872, p. 240.

[The fruits or flowers of many Indian forest trees are utilized in various ways; those of the **Mahua** or **Mowra** (*Bassia latifolia*) are very valuable. A kind of edible butter or oil is made from the kernels of the seeds, from which also candles and soap are made. The succulent corollæ of the flowers are also eaten raw or cooked, and resemble inferior figs in flavour; from them sugar is also made. The dried flowers are, however, chiefly used in the manufacture of spirit, resembling Irish whiskey. Dried Mahua flowers form a considerable article of trade, but are now prohibited in France, where they were imported for making brandy.

Fruits of *Terminalia Chebula* and other Terminalias, termed **Myrabolans** are largely used as black dyes, and in fixing other dyes. In 1889—90, 678,502 cwt., worth about £140,000, were exported from India, chiefly to the United Kingdom.—Watt. Ind. Economic Dictionary.]

CHAPTER V.

DRY FALLEN WOOD.

By the term **dry fallen wood** is meant all dead branches and twigs lying on the ground and broken from off the trees, either owing to the natural thinning process, or by wind, snow-break, &c., and which may be employed as firewood without using any implements—in fact, can be broken on the knee or by the hand.

This is the strict definition of dry fallen wood: but the looseness of interpretation of the term, as frequently employed, may be gathered from the fact, that in many places all dry branchwood still attached to the trees is included; in other places it is applied to inferior root- and stump-wood, which is not saleable and therefore not up-rooted, also to all unsaleable refuse-wood left on the felling-areas. In some districts the collectors of dry fallen wood (*Leseholz*) are permitted to cut down and appropriate dead saplings and small poles.

The collection of dry fallen wood is a very simple affair; it is gathered from off the ground, and when dead branches attached to trees are included, they are pulled off the trees by means of iron hooks at the end of long poles, or by climbing the tree and lopping them with the axe. The quantity of dry fallen wood produced, and the importance of its collection, from national-economic and sylvicultural aspects, will prove more interesting.

1. *Quantity of Dry Fallen Wood available.*

The quantity of dry wood falling on a given area in a certain time, varies greatly according to circumstances: it depends principally—on the extension of the meaning of the term; the density and age of the standing crop, and the species of which it is composed; the nature of the thinnings, whether heavy or light, also on the climate (snow- and ice-break). Averages cannot be given with any certainty of the absolute amount of fallen dead wood, owing to the variability of the above-mentioned factors and the want of sufficiently extensive observations.

It will not be an over-estimate to place the average amount of the fallen dead wood at 12 to 15 % of the regular yield of a forest (this does not apply to plantations with the plants wide apart).

(a) **Extension of Interpretation of the term Dry Fallen Wood.**—Obviously, there must be a great increase in the amount of dry fallen wood, if it also includes dead branches on the trees, or if its collectors are allowed to cut down and appropriate dead saplings and poles.

(b) **Density of Crop.**—The denser the standing crop, the more dry wood is produced. The mode of regeneration adopted is influential here, there being a considerable difference in the amount of dry wood if the crop of trees has been formed by natural regeneration by seed, or by more or less dense sowing or planting. The plantations of the present day yield far less intermediate produce, and consequently less dry wood, than natural regeneration or artificial sowings. In the Harz Mountains attempts are still made to justify multiple planting owing to its greater yield of intermediate produce.

(c) **Locality and Rate of Growth.**—The more favourable a locality, the greater the yield of wood. This increased yield of wood is favoured by the stronger individual growth of the dominating trees, and the greater height to which they grow: a quicker and more vigorous struggle for existence between the trees then ensues, and stems and branches deprived of light by those above them soon perish. Other circumstances being similar, a good locality therefore produces more dry wood than an inferior locality.

(d) **Age of the Crop.**—The shedding of dry wood is at its maximum in young pole-woods. The yield from thinnings continues indeed to increase after this period, but not that of dry wood, which keeps on declining more or less rapidly according to the quality of the locality and the density of the crop. The earlier thinnings commence, and the intermediate yield is regularly utilized, the less the amount of dry wood.

2. *Importance of Dry Wood from National-Economic and Sylvicultural Aspects.*

When the immense amount of dry wood is considered, which in many places is gathered weekly by the poor and forms a large proportion of their winter supply of fuel, its national economic importance is obvious. Even when firewood-prices are at their lowest in well-wooded districts, this usage is always practised. It has been maintained that the collection of dry wood is a waste of labour which might be more profitably applied in other directions; this may, however, be controverted.

Wherever the country people are chiefly employed in agriculture, there are certain slack times in every year which they can devote to collecting firewood for their own household requirements. It cannot be denied that labour might be more profitably employed than in collecting dry wood, but it should also be remembered that country folk, and especially those living near extensive woodlands, are not acquainted with national-economic laws and are usually satisfied with obtaining the bare means of living. Country labourers, however, are severing themselves more and more from old customs, and obtaining better markets for their labour, so that it is chiefly children and weaker people who gather dry wood.

[In India, dry fallen wood is freely given from the State forests and others to villagers and travellers; large quantities of firewood are also gathered by the people free of any charge from the driftwood which is stranded by the numerous rivers during and after the monsoons.—TR.]

The sylvicultural importance of dry fallen wood depends chiefly on its value in enriching and loosening the soil, the protection it affords to dead leaves in exposed places (preventing the wind from blowing them away); also when properly supervised, on the careful removal of dead branches from trees to render them free from knots.

It is well-known that dry twigs and branches decompose in the same way as dead leaves, needles and other organic bodies, and thus increase the supply of humus. The physical effect is still more important, for pieces of dry wood becoming gradually buried in dead leaves loosen the upper strata of soil and expedite the formation of humus, an important point in the case of wet and binding soils. Moreover, the coating of dead leaves when mixed with pieces of dry wood is not so easily removed by wind, a property not to be despised for exposed beech-woods on poor soil. In woods which have been sown artificially or naturally, the stems free themselves of their dead branches. This, however, in modern plantations, is not completely secured without pruning; the branches otherwise become enclosed within the stems and thus depreciate the value of planks and scantling obtained from the trees. In such cases it is best to employ paid labour to prune the trees: where, however, the collectors of dry wood are properly supervised and allowed to remove dead branches with small hand-saws, the cost of pruning is saved, and damage avoided which may be considerable when the dry branches are roughly removed.

CHAPTER VI.

UTILIZATION OF STONE, GRAVEL, ETC.

In mountain-forests, the utilization of stone is frequently an importent item of forest revenue; quarrying the better kinds of stone increases in importance with the expansion of towns, the more substantial nature of the buildings erected and the constantly extending means of communication. Independently of the fact, that an absolutely necessary want is thus met, the forest owner's own pecuniary interest will prevent him from opposing a well-regulated system of quarrying, for the best production of wood will never pay so well as leasing quarries.

1. *Different kinds of Stone.*

The following kinds of stone are utilized:—**Hewn-stone** which is regularly shaped, and for which the fine, compact sandstones of the Cambrian, Silurian, New Red Sandstone and Tertiary formations, also trachyte among eruptive rocks, &c., are most in demand. [In Britain also Bath oolite, Aberdeen granite, &c. —Tr.]

Broken stone used in **rubble-masonry**, for foundations, &c., for which almost any kind of stone is suitable;—or **paving stones**, for which the hardest material, basalt, phonolith, diorite, fine-grained syenite, &c., are most suitable. **Slate** for roofing from the Cambrian and Silurian formations, and **lignite** near Liegnitz and Frankfort are also valuable. The forester should everywhere favour quarrying, not only on financial grounds, but also for national-economic reasons. Calcareous rocks are also of great importance, serving as building-stone or for lime-burning, for which purpose they are the more valuable the less clay they contain. Quarries of gypsum, felspar and kaolin are rare. The list may be closed by enumerating sand, gravel, marl and clay, which are almost everywhere more or less in demand.

2. *Mode of Utilization.*

Stone is obtained either by quarrying the mountain-side, or by collecting boulders or flint-nodules from the surface of the ground. From a sylvicultural point of view, permanent quarries are greatly preferable to the employment of boulders, as the area taken from the production of wood is then of limited extent and more easily controlled: the growth of wood being permanently excluded from the area, no question of indirect injury to the forest can arise. Direct injury to the forest may, however, occur in quarrying—in the experimental search for suitable localities for a quarry; the loss of wood production on areas which are often extensive; the damage to roads, and occasionally the increase in forest offences owing to the presence of the quarry-men in the forest.

The quality of stone from the same geological formation may vary considerably in different parts of the same mountain-side; hence several experimental quarries are frequently commenced and eventually abandoned. This causes loss of a considerable area for wood-production, as when the soil is covered with fresh unweathered rock it is often impossible to restock it with trees. Even when a workable quarry has been started, fairly large areas are often required for deposit of the refuse stone, and on steep slopes the latter often accumulates in long strips down the valleys, as in the Siebengebirge.

This nuisance may, however, be improved by good regulations and confined within reasonable limits. It is therefore indispensable that not only the quarry itself, but the area on which refuse may be thrown should be carefully demarcated. Forest offences by quarry-men, who are sometimes imperfectly acquainted with the limits of mine and thine, cannot be altogether avoided. Considerable damage is also done to the forest roads, no traffic being more ruinous to them than that of stones from quarries. The latter are not usually important enough to warrant the construction of roads specially made for them alone; hence the nearest forest road is used, and if the expense of its maintenance falls exclusively on the forest owner, this may cost him more than he obtains from the stone-quarry. In such cases, a condition should be entered in the lease of the quarry for payment by the lessee for maintaining the road in good condition.

Although regular quarries are usually more profitable than the mere collection of boulders, the latter are often harder and drier than freshly quarried stone from the damp mountain-side, and are, therefore, much used for rough building purposes if the slope on which they are lying is steep enough to facilitate their collection, and roads are available for their removal from the forest.

As in this case, the stones are collected from among trees, damage to the standing crop is always to be feared, and especially to the roots of the trees. It is the interest of the lessee, however, to be careful, as he would otherwise lose the business, so that the best precautions against damage are usually taken.

[Considerable damage is done to the roots of trees in the forests of Normandy, by removal of superficial flint-nodules. It should also be noted that large stones lying in regeneration-areas often preserve moisture in the soil and their removal should therefore be restricted to older woods, in which the cover has not been interrupted.—Tr.]

The forest owner rarely undertakes the quarrying or removal of stones at his own expense; even if he should require the stones for buildings, walls or road-metalling, it is better to obtain them by contract, rather than by daily labour. Hence it is usual to lease quarries. The limited local demand for sand, gravel, forest soil, &c., is generally met by permits, at rates agreed upon per hundred cubic feet or cartload, from the more or less permanent sand or gravel-pits.

[In the north of India, considerable revenues are obtained by leasing the limestone-boulders in the beds of watercourses, which are dry for 8 months in the year; lime-burning has the further advantage of causing a large demand for firewood, for which it is often difficult otherwise to find a market.—Tr.]

CHAPTER VII.

THE USE OF FOREST LITTER.

SECTION I.—GENERAL ACCOUNT.

IN forests, the mineral soil is not exposed, but is everywhere coated with a vegetable **soil-covering** which is partly dead and partly composed of living plants. When a dense broad-leaved forest is left to nature, its soil-covering consists of dead leaves, husks of fruit, fallen flowers, &c., which the trees shed periodically and with which dead fallen branches and twigs are mingled. In a dense coniferous forest, the soil-covering consists of living and dead mosses, among which are the dead fallen needles. Wherever the soil is exposed to the influence of light, and in more or less open woods, the soil also produces a number of weeds of various species.

If this covering is removed from the soil, the productiveness of the latter is greatly affected and in most cases deteriorates: not unfrequently its power of producing wood may be completely arrested. This removal of the soil-covering has in many forests become a more or less regular custom and has unfortunately assumed the character of a forest usage termed **removal of forest litter**, the litter being used in stalls and stables instead of straw.

Whenever the soil-covering of a forest, consisting of dead leaves or needles and moss, is left to the natural process of decomposition, its lowest layers completely lose their organic character, only their mineral components being left. More and more organic matter is thus found in its upper layers, till the surface consists of dead leaves or living moss. Its lower and partly decomposed layer is termed **humus** and its upper decomposing and living layers, **litter**. While therefore in humus all vegetable structure has completely disappeared, in litter (*Streu*), this structure is quite recognizable. Humus cannot be used in stalls for litter, but it has some value as manure and is therefore appreciated by the farmer as an adjunct to litter. It is thus generally the undecomposed layers of the soil-covering only which are used as litter in agriculture. Forest litter may therefore consist of various materials, which have different values as substitutes for straw and are collected in various ways. Besides ground-litter, the young twigs of conifers are also used as stable litter. Hence a distinction is made between the following kinds of forest litter :—

A. **Ground-Litter**, including all dead or living materials from the soil-covering of forests, which may consist of :—

(a) **Dry fallen leaves or needles**, which are shed by the trees forming the standing crop of the forest ; and to some extent, by shrubs in the underwood.

(b) **Moss and grass**, partly living and partly dead.

(c) **Forest weeds**, such as broom, bilberry-plants (and other species of *Vaccinium*), heather, ferns, reeds, rushes, &c.

B. **Branch-Litter**, young needle-bearing twigs of the Scotch pine, spruce, silver-fir and larch.

SECTION II.—IMPORTANCE OF FOREST LITTER FOR WOOD-PRODUCTION.*

Foresters have always endeavoured to preserve the forest soil-covering of humus and litter ; these materials have indeed for a long time been recognized as the natural means of preserving the productiveness of the soil and preventing deterioration of the forest, which is in no way more endangered than by their removal.

1. *Beneficial Effects of Litter and Humus on the Growth of Trees.*

(a) **Preservation of moisture in the soil.**—The humus which covers the mineral subsoil and is only to a slight extent mixed with it, and the coating of litter above the humus, are the most effectual means of securing and maintaining in the soil the requisite amount of moisture. The action of humus and litter is in this respect threefold, *viz.*: The **mechanical impediment** it affords on slopes to **rapid drainage** of surface-water from atmospheric precipitations, and the time thus allowed for the water to sink into the soil-covering and the soil; the sponge-like action possessed by dead leaves and moss of **absorbing and retaining water**, and the consequent **reduced evaporation** of water from the soil.

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* Ebermayer, Die gesammte Lehre der Waldstreu, Berlin, 1876.

Without a sufficient supply of water, other productive agencies of the soil are unavailing; it may therefore be affirmed that the most important influence of the soil-covering on woody growth is the supply of water it affords. Only about three-quarters of the rain falling on the leaf-canopy of a forest actually reaches the ground, much of it being broken into spray by the branches and foliage and re-absorbed by the air. So much the more important is it, that forest soil, as compared with cleared land, should have the means of utilizing all rain-water it secures.

Most of the rain-water falling on a mountain-side, where the soil has been deprived of litter, moss and humus and has consequently become hard and compact, runs down to the valleys, only a small part of it soaking into the soil. If, however, the spongy soil-covering has been preserved, much of the rain penetrates it and is retained, gradually draining down into the ground. This mechanical action of the soil-covering is therefore highly important in mountain-forests.

The water which the soil thus secures is also most thoroughly retained by the absorptive action of the soil-covering; dry coniferous needles can absorb 4 to 5 times their weight in water, dry beech leaves 7 times, and mosses 6 to 10 times this amount, without allowing it to dribble away. This absorptive power of the soil-covering is further increased by that of humus for water-vapour, which, becoming condensed in the cool soil, increases the supply of moisture. Once the soil-covering is thoroughly saturated with water from atmospheric precipitations, it passes on the superfluous water to the subjacent soil in the numerous interstices of which it is distributed, and thus reaches the roots of the trees.

When, however, a mossy soil-covering becomes very thick, and the rainfall is slight, it may happen that it retains all the water and allows none to reach the soil. This usually happens, however, late in the summer when assimilation is about ended for the year.

The soil-covering finally acts by protecting the soil from the evaporation of the water it contains. The water ascending by capillarity from the soil finds in the larger interstices of the soil-covering an impediment to the continuance of this action up to the surface; it therefore collects in the lower strata of the soil-covering and is re-absorbed by the soil as the atmosphere cools down in the evening. Ebermayer* has experimentally shown that the evaporation of water from a forest-soil protected by litter is 2½ times less than when the litter has been removed. In this respect the difference between dead leaves and moss should be noted. Wallney has shown that a soil-covering composed of beech leaves is the best preservative against evaporation; it is much more effective than the mossy soil-covering of coniferous forests, which dries up rapidly in summer.

Whenever the soil is otherwise supplied with sufficient moisture, either owing to its hygroscopic power or a more than usual supply of water—as in sweating sand (*Schwitzsand*), when the level of subsoil-water is high; in narrow valleys, mountain terraces, depressions in plains and plateaux, &c.—a soil-covering of humus and litter is of less importance in this respect. It may even prove injurious in localities, which, without its aid, are too wet. In all other cases its importance is the greater, the less hygroscopic the soil—in sandy and calcareous soils, all shallow soils, loose gravels and masses of boulders—which can only retain water when covered with humus and litter. It is also obviously more important on slopes than on level ground.

(*b*) **Influence on porosity of the soil.**—The activity of a soil also depends on its porosity, which affords interstices in it for the circulation of air and renewed supplies of oxygen. Litter and humus keep the soil loose and prevent its becoming caked by the rain.

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* Die Physikalischen Einwirkungen des Waldes auf Luft und Boden.

By mixing soils of various degrees of compacity with humus, a suitable degree of porosity may be secured, as is often seen in lands periodically flooded. Where humus is produced. especially in mountainous districts, it does not become mixed with the soil, but merely covers it, rarely penetrating it more than an inch or two. The admirable condition of the soil, however, which is termed "fresh," is usually accompanied by a suitable degree of porosity; when fresh, a soil is as it were raised and porous, without being saturated with water; whilst dry soil, unprotected by a soil-covering of litter and humus, becomes more quickly compact and superficially hard, the more exposed it is to be beaten down by the falling rain-drops.

Besides, as the particles of humus become more and more oxidised and pass into fresh chemical combinations, such as soluble salts, the process of diffusion causes movements within the soil, which highly assist in increasing its porosity and activity, whenever it is protected by a suitable soil-covering. At the same time, this process is assisted by the decomposing dead roots of felled trees remaining in the soil and by the tunnelling of earthworms, mice, moles, lizards, grubs, insects, &c., whenever the soil is protected by a soil-covering.

(c) **Maintenance of a steady temperature in the soil.**—The presence of the soil-covering acts further, in maintaining a fairly steady temperature in the soil, a condition, the importance of which should not be underrated for any trees, and especially for those which are shallow-rooted. Just as the closed leaf-canopy of a forest secures it from wide ranges of temperature, when compared with cleared land, so also, extremes of temperature in the soil are moderated by the soil-covering: the fact that this is very beneficial to roots spreading in the upper layers of the soil has been conclusively proved by the disastrous results of removing litter.

(d) **Fertility of the soil.**—Humus has finally most important effects on the fertility of forest soil. It is well-known that undecomposed humus does not afford sufficient nutriment for plants, but nevertheless it influences the fertility of the soil very considerably; in the first place, by its physical action on soil, and secondly, by providing from its own decomposition the means of disintegrating the subsoil and rendering the nutritive matter contained in it soluble.

i. Physical Action of Humus.

The physical action of humus is beneficial owing to its power of absorbing water and watery vapour, as well as some of the most nutritious mineral substances (potash, phosphoric acid, ammonia, &c.), from their soluble compounds and supplying them to plants; also for its retention of heat.

Fine earthy particles have similar properties, but not more so than humus. The soil-strata containing the roots of plants is thus protected, to a certain extent, from loss by drainage of these important substances.

ii. Residual Products of Decomposed Humus.

The residual products of decomposed humus are ash, carbon dioxide and water; they form, partly alone and partly in combination as salts, the nutritive material or manure for the forest. In the ash resulting from the decomposition of humus, the nutritive mineral substances which have been taken from the soil for the production of wood are returned to it in a form that is most easily assimilable.

The extent to which nutritive mineral matter, the so-called ash-constituents of a soil, furthers the growth of plants, is proved by the effects of manure in agriculture, the improved growth of manured forest nurseries and the enhanced wood-production of minerally rich, as compared with minerally poor soils. Trees retain the ash-constituents in different degrees in their several parts, and at different seasons of the year. The stem is poorest in this respect, the more so the older it is; green branches are richer in ash the younger they are; still richer is the bark, especially in the upper parts of the tree. Leaves and needles, however, contain the greatest proportion of ash.

The following table gives the amount of ash in needles and leaves :—

Dead leaves or needles of :—	According to	
	Stockhardt.*	Ebermayer.†
	Percentage of ash.	
Spruce	7·13	4·00
Beech	7·12	5·57
Larch	5·50	4·00
Scotch pine	2·58	1·46
Oak	—	4·30
Silver-fir	—	3·78

On comparing the demands of trees with those of agricultural crops on the mineral matter in soils, the former is bound to be considerable, for an acre of beech forest requires more mineral matter than an acre of wheat, and spruce forest nearly as much as the latter. It is, however, well-known that a great part of these necessary mineral substances, on account of their wide-spread dissemination, affords little cause for anxiety and that only a few substances are really decisive as to the fertility of a soil; these are sulphates, phosphates, potash salts and lime. In comparing forestry with agriculture, only these substances need be considered; in their case the demands of forestry for the production of wood are far behind those of agriculture.

On account of the slight demand made by forestry on the more important mineral nutritive substances, and the fact that a portion of them return to the sapwood and young twigs before leaf-fall, it might be conjectured that forest litter is not indispensable for the soil, owing to the small amount of important mineral matter it contains. It should, however, be remembered that, independently of the importance of forest litter in other respects, most forest soils are poor in these very mineral substances, and although the demands made on them by forest trees are small, yet they are continuous; the necessary consequences of the removal of litter must therefore be similar to those which follow a want of manure in agriculture. How greatly the soil thus loses in important chemical constituents (in phosphoric acid for instance) may be gathered from the fact that a soil formerly stocked with broadleaved trees may, owing to the removal of litter, contain only 0·012 to 0·020 % of phosphoric acid and thus become fit only for Scotch pine. For, according to Weber, at least 0·050 % of phosphoric acid is required in soils by broadleaved trees. Another important point is the scarcity of lime in most sandy soils, whilst much lime is required by most trees. It is also well-known that the indispensable supply of nitrogen depends on the quantity of humus in soils. When it is further considered that the nourishment of plants depends chiefly on a sufficiency of assimilable ash-constituents, which owing to the small proportion of fine earth in many soils can hardly be supplied except by humus, there can be no doubt that most forest soils absolutely require the ash-constituents of humus. This is especially the case with sandy soils, which are usually poor in lime and potash, and with localities liable to inundations, which may wash these substances out of the soil; forest litter is then almost the only source of mineral matter, the only supply of manure.

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* Der chemische Ackersmann, 1862.

† Tharandter Jahrbuch, vol. 15, p. 322.

In soils containing humus, according to Frank, fungi which form a *mycorhiza* on the roots of most forest trees are always present, they are absent in soil deprived of humus [or artificially sterilised by burning.—Tr.] and a long time passes before mycorhizas are produced. Owing to this *symbiosis* of plants and fungi, the former not only derive nutritive matter through the humus, but are even enabled to obtain nitrogenous substance indirectly from the atmosphere.

Owing to the utilization of timber and other forest produce, the nutritive substances obtained from humus are not sufficient for the growth of trees; fresh material must therefore be taken from the sub-soil and supplied to the soil in an assimilable form. Among the substances which effect the disintegration and solubility of parts of the sub-soil, besides various salts, the carbon-dioxide resulting from the decomposition of humus plays a very important part and without its assistance the soil cannot remain continuously active. The efficacy of carbon-dioxide is not only confined to the topmost layers of soil formed by the litter, but also exerts itself wherever the roots of the trees penetrate. The presence of dead roots in the soil is not therefore a matter of indifference and it may be doubted whether the extraction of stumps is not prejudicial to the fertility of the soil.

Humus yields not only assimilable mineral nutriment, but also the carbon-dioxide necessary for extracting nutriment from the sub-soil; it is therefore indispensable for the nourishment of plants both in poor and rich soils. It is also obvious that a scarcity of humus must be prejudicial to the production of wood, owing to the enormous requirements of carbon-dioxide by plants and the large quantity of this gas passed into the air by decomposing organic matter.

2. *Mode of Decomposition of Forest Litter.*

In describing the beneficial effects of forest litter and humus the manner in which their decomposition is effected has been pre-supposed, but now requires some explanation. It is well-known that the decomposition of all organic matter can only be effected by the agency of **bacteria** (fission-fungi). The necessary conditions for the life of these organisms are the action of air, and of a certain amount of moisture and heat, [whilst light is prejudicial to them.—Tr.]. Hence it follows—as those factors are not always equally effective, sometimes one and sometimes another of them preponderating and some vegetable substances decomposing more readily than others—that the rate of decomposition varies in different cases and the products of decomposition themselves are variable.

The comparative rate of the decomposition of forest litter and humus is chiefly influenced by the **kind of soil-covering, soil, locality, climate, nature of standing crop,** &c.

(a) **Kind of Soil-Covering.**—Soft and only slightly lignified parts of plants decompose most rapidly. Thus, of broad-leaved trees, the dead leaves of the hornbeam, ash and lime decompose more rapidly than those of oak, beech and birch. Of conifers, larch needles are soonest decomposed, then Scotch pine needles, then those of silver-fir, and most slowly, those of spruce. It is generally true, that dry leaves of broad-leaved trees decompose more rapidly than coniferous needles. Mosses are known to decompose very slowly; but their decomposition once commenced, passes quickly through the condition of humus to that of complete dissolution. On this account, the living layer of moss rests on the ground with hardly any noticeable intermediate layer and may be removed from it like a carpet.

(b) **Soil.**—The most important factors in the soil which expedite decomposition of the soil-covering, are its capacity for heat, its degree of porosity and the amount of moisture it contains. Decomposition is generally slowest on clay or loam, quickest on calcareous soil and sand. It is especially rapid on moist calcareous soil in South Germany; after two years most of the litter is decomposed, the humus decomposing still more quickly.

(c) **Locality.**—It is well-known that decomposition proceeds more slowly on north and east than on south and west aspects; northerly slopes are damp and cool, and in folds of the hills near the valleys the rate of decomposition is extremely slow: in such places the greatest amount of partly decomposed humus and litter accumulates.

(d) **Climate.**—Southern countries prove strikingly that heat combined with moisture is most effective in expediting decomposition; in South Germany, and still more in Hungary, &c. decomposition proceeds much more rapidly than in North Germany and the countries bordering on the Baltic. Whilst in the latter case 3 or 4 years are often required to complete the process of decomposition, one or at most two years suffice for the former. [In an Indian forest, except in mountainous districts, it is rare to find any noticeable layer of humus in forests.—Tr.] The contrasting climates of the lowlands and high mountain-regions of Europe have opposite effects on decomposition; the high relative humidity of the air and low mean temperature in mountain tracts cause deep layers of raw humus to accumulate in forests, fallen wood may there be found which has hardly made any progress in decomposition during a century or more.

(e) **Density of Standing-Crop of Trees.**—The denser a wood, other conditions being similar, the slower the decomposition of forest litter. Densely growing poles shelter the soil from air and heat, by their complete cover they hinder evaporation of water from the soil, and hence retain much moisture in the surface-soil. [Not, however, in the soil containing their roots, which is well drained by the demands of the growing poles for water, transpired by their crowns into the atmosphere.—Tr.] Hence in dense pole-woods of spruce, beech and silver-fir, especially on northerly aspects, there is always plenty of half-decomposed litter and humus. Woods of old light-demanding trees show opposite phenomena. The Scotch pine loses its soil-improving character soon after light gains admission to the ground. [In Britain, generally at an age of about 60 years. —Tr.]

(f) **System of Management.**—Decomposition of litter is undoubtedly slowest in even-aged high forests, and here (unless it is removed periodically) the greatest amount of undecomposed and partly decomposed litter is found. Coppice forms the other extreme; litter there decomposes the more quickly, the shorter the rotation and the more open the crop (as in oak-bark coppice). A light growth of herbage may be then considered beneficial. Coppice-with-standards also resembles coppice in this respect. Whilst under the above-mentioned systems the rate of decomposition varies with the age of the crop, in Selection-forest this rate is invariable, though owing to the moderate access of heat, light and air and the moisture preserved in the soil by the groups of underwood, it is moderately fast. For this reason, in the still existing virgin forests of Germany the amount of humus and litter imagination may have pictured does not exist; under otherwise equal conditions, the amount of humus in them is frequently less than in any dense pole-woods of Scotch pines or spruce managed under the clear-cutting, high forest system.

3. *Products of Decomposition of the Soil-Covering.*

The nature of the products of the decomposition of the soil-covering depends on the rapidity with which it proceeds. According to Ebermayer (op. cit. p. 580), they may be classed under three principal heads as **sour, dry** and **mild humus.**

(a) **Sour humus.**—Sour humus is formed on wet soils which exclude the air and do not contain enough oxygen; the decomposition of the soil-covering, therefore, proceeds very slowly and is incomplete. Sour humus is formed in swamps and fens and has an acid reaction owing to the absence of alkalis or bases. It also occurs in poor sandy districts, where it passes into the form of dry humus. Sour humus and the consequent acidity of the soil in which the roots of trees grow, are the greatest possible hindrances to the growth of most European woody species.

The beech is most sensitive to the action of sour humus; oaks, sycamore and other maples, Scotch pine and spruce withstand it better; alder, birch, poplars, and willows are not affected. It is well known that rhododendrons, azaleas and camellias thrive on sour humus.

(b) **Dry humus.**—Dry humus is the product of a decomposition, in which plenty of air and heat are the chief factors, but moisture is limited. Whilst in sour humus all the interstices of the soil are filled with water and mild humus forms a loose moist mass, dry humus is rich in ash and carbon and when quite dry is a mere dust. It is formed wherever there is free access of air and heat, and insufficient moisture; as on dry moorlands, southerly slopes, blanks in forests, clear-cut felling-areas, over-thinned old woods, especially on poor sandy soils and above hot calcareous rocks.

This kind of humus [resulting from the decomposition of heather, grasses, and Iceland moss (*Cladonia rangiferina*)] is not beneficial to vegetation, as the light dusty soil is easily blown away and has besides very little nutritive properties; being rich in carbon, after it has lost nearly all its moisture and oxygen its further decomposition is difficult, it adds little to the chemical ingredients of soils, and supplies very little carbon dioxide to the subsoil. Being deficient in alkalis it is sour, and is the chief cause of the formation of moor-pan; heather-soil is its commonest form.

(c) **Mild humus.**—Mild humus, known also as forest humus or leaf-soil, results from the chemical change in forest litter to which air has free access, and when sufficient heat and moisture are present to hasten the process. Free organic acids are not then formed, but are combined with alkalis, the decomposition liberating only carbon dioxide and water. The beneficial effects of humus on the fertility of the soil can then act unimpaired, a mild humus which is very useful in the production of wood resulting from the decomposition of the soil-covering in forests.

That humus should have a neutral or basic action on the soil is a necessary condition for the successful growth of most forest trees. The cultivation of beech, silver-fir and hornbeam appears to depend on it. In mountain-regions and wherever the soil containing the roots of trees is formed by the disintegration of the subjacent rock (the sub-soil water not being stagnant) the soil has a neutral reaction. The contrary happens in the sandy plains of North Germany and in countries bordering on the Baltic, especially in Schleswig-Holstein [also in extensive sandy heather-tracts in the British Isles.—Tr.]

If, therefore, humus is to act beneficially on soils, the decomposition of the soil-covering must be moderately rapid and continuous. For then only are those chemical constituents of soils replaced which have been used in plant-growth, whilst, at the same time, a sufficient quantity of litter and humus remains as an indispensable covering of the soil.

Decomposition often proceeds differently in the different strata of the soil-covering: whilst chemical change predominates in its upper strata, the lower strata rather putrefy; chemical change is, however, the more active agent, especially in localities with a dense standing crop of trees. Although it is difficult to state the exact time required, it may be alleged that for ordinary forest localities, humus is formed in the most beneficial manner when the soil-covering of dead leaves is decomposed in two or three years and that of dead needles in three or four years, the underlying stratum of humus being about a centimeter (one-third of an inch) thick.

4. *Summary.*

To resume all that has been said in the preceding pages about humus, it must be admitted that it is the chief factor in the fertility of soils. Whenever the forester has to produce the greatest quantity of wood of the best quality, he must maintain continuously the productiveness of the soil by all the means in his power. Of these, none is more effective than preserving humus in the most suitable condition. However abundant chemical nutriment may be in rich soils, it is worthless, unless the means for rendering it soluble (carbon dioxide and water) are present. A rich soil can dispense with humus better than a poor soil, but in the long run must fall back upon it.

As poor land rather than rich land is usually stocked with forests, forest-litter may always be considered **the most indispensable and effective factor for the growth of trees.***

SECTION III.—AMOUNT OF FOREST LITTER PRODUCED.

Owing to the importance of moss and weeds as well as dead leaves and needles in the supply of litter for farmyards, the different nature of these kinds of litter and the various ways in which they affect wood-production, it is necessary to consider the question separately for each kind of forest litter.

1. *Dead Leaves and Needles.*

Experience shows that the annual amount of litter produced from dead leaves and needles in a forest varies with the species of tree, locality, weather, density of crop and age of trees.

(a) **Species of tree.**—Three factors have great influence on the amount of litter produced by European forest trees; namely, the **density of the foliage**, its **duration** on the trees and the suitability of the species to form a more or less dense **leaf-canopy.** Considering all these factors, not for individual trees but for a whole wood, and deducting the amount of moss produced in coniferous forests, the species may be arranged as follows in descending order of their comparative production of dead leaves or needles:—

Beech;
Sycamore and other maples, lime, sweet chestnut, hazel;
Hornbeam, alder, black pine;
Elms, oaks, black poplar;
Scotch pine, larch;
Spruce, silver-fir;
Ash;
Birch, aspen.

The **density of foliage** of a species depends on the nature of the locality and its mode of growth. Silver-fir, spruce and beech have the densest foliage; that of sycamore, lime, sweet chestnut and hazel is also dense though comparatively lighter than the above; black pine, alder, and hornbeam follow these closely. Oaks, black poplar and ash come some way behind the last group; Scotch pine and larch produce still less foliage, whilst birch and aspen close the list.

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* See the interesting paper by Oberforstrath Braun in Borgreve's Forstliche Blätter, 1890, on the importance of forest litter for the soil.

The **duration of the leaves on the trees** is evidently longest for evergreen conifers, silver-fir, spruce and pines. In the case of the black, Weymouth and Scotch pines, the needles remain from two to four years; in the spruce and silver-fir, four to six years and even longer for the latter. Hence it follows that pines shed about one-third of their foliage annually, the spruce and silver-fir only the fifth or sixth part. These species, therefore, are much worse producers of litter than follows from the density of their foliage.

Silver-fir, spruce and beech possess in the highest degree the property of growing in **densely stocked woods**, next come the hornbeam and hazel—some way further down in the list—alder and sycamore. In the case of ash, elms, oaks, sweet chestnut, birch, aspen, Scotch pine and larch, the woods open out much earlier. As compared with woods of light-demanding trees, those of mixed light-demanders and shade-bearers produce more litter, whilst woods of spruce, silver-fir and beech produce litter most abundantly.

(b) **Locality.**—The nature of the locality in which it is grown has the greatest possible influence on the well-being of a species of tree. The more a locality suits a tree, the greater, other conditions being equal, will be the production of litter. As a rule, a moist atmosphere, provided there is sufficient heat available for the species in question and a rich soil, increases the density of the foliage.

Localities with high relative atmospheric humidity produce a much denser leaf-canopy than those where the air is dry; the spruce in high mountain-regions, the beech in extensive woodlands, the hornbeam, alder and birch in damp lowlands near the Baltic, produce much more foliage than the same trees in other localities. The better the soil, the deeper and denser the leaf-canopy; but the soil and local climate must always be considered together. The aspect is also influential, as owing to their greater moisture, north and east aspects produce as a rule most litter. R. Weber's* note on beech leaf-production should also be noted, viz., that it falls off in quantity with the altitude.

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* Ebermayer, Die Waldstreu, p. 37.

(c) **Weather.**—Any casual observer must have noticed that according to the changes of weather in different years, the forest presents different appearances, being in certain years fresher, greener and possessing denser foliage than at other times. Spring-weather is most decisive in this respect. Years with severe late frosts and dry seasons produce less foliage than moist years free from frost. According to Krutzsch, there may be a difference of 60 % in the amount of foliage produced by Scotch pine and beech in wet and dry years.

The duration of the foliage of evergreen trees depends on their shade-bearing properties and age, on the climate, the comparative density of the crop, frosts and nature of the weather in spring. As a rule, leaves persist longer in southern than in northern latitudes. The amount of rainfall is very influential; with heavy rainfall needles which should fall normally remain on the trees, and whenever a dry year follows a damp one, needles of two or three consecutive years may all fall together.

(d) **Density of growth and system of management.**—The production of foliage depends on the free admission of light to the trees; the more a tree is exposed on all sides to light, the larger its crown. A tree, therefore, standing in the open produces far more litter annually than a tree of the same species grown in a dense wood.

The densest woods do not produce most litter, nor do open woods where each tree is completely exposed to the influence of light, the number of individual trees being then too few. The most litter is produced annually when there are as many stems as possible in a wood, with the proviso that each stem has ample room for its growth—a density which results from well executed thinnings.

Even-aged woods exercise a similar influence to that of the density of woods on the annual supply of litter. When all trees in a wood are of the same height and their crowns form a dense leaf-canopy at a uniform level above the ground, the influence of light is far less than when the heights of the trees vary, when lateral light is admitted between the groups of the taller trees and their crowns consequently grow lower down their stems.

Even-aged woods, therefore, do not produce as much annual litter as uneven-aged selection-woods, double-storied woods (with overwood and underwood) or woods managed according to the group-system. Well-stocked coppice-with-standards on good soil may yield annually even more litter than even-aged high forest.*

(e) **Age of trees.**—The greatest production of dead leaves and needles is during the pole stage, and only slightly falls off in the older stages of high forest, provided the leaf-canopy is fairly complete.

Whenever no direct experimental results as to the amount of litter in a forest are available, estimates of the quantity of litter are necessarily based on the physiological fact that the annual production of foliage is very nearly proportional to the annual production of wood. The results of the Bavarian investigations has not so completely confirmed this rule as was expected, but all sylvicultural observations tend to prove the existence of a fixed ratio between the amount of foliage and the wood-increment.

The following results give the average yield of litter as determined by observation† made in the Bavarian State forests.

One acre of dense forest of the ages given in the subjoined statement produces annually so many tons of air-dried litter :—

Age of wood.	Beech.	Spruce.	Scotch pine.
Years.	Tons.	Tons.	Tons.
Under 30	—	2·50	—
25 to 50	—	—	1·56
30 to 60	1·67	1·58	—
50 to 75	—	—	1·4
60 to 90	1·64	1·35	—
75 to 100	—	—	1·69
Over 90	1·62	1·31	—
Average	1·64	1·42	1·48

It is evident that when the litter is allowed to accumulate in a forest for several years, the supply is greater than that produced annually. At the same time the accumulation is limited, as the lower layers are constantly decomposing and only the upper layers are available litter. In this respect investigation has led to the adoption of the following average figures per acre :—

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* [The apparent contradiction between this statement and that in (f), p. 589, is due to the fact that here the annual supply of litter is referred to, and there, the accumulated amount of litter undisturbed for years.—Tr.]

† Ebermayer, Die gesammte Lehre der Waldstreu, Berlin, 1876.

No. of years.	Beech.	Spruce.	Scotch pine.
	Tons.	Tons.	Tons.
3 years' supply	3·26	3·04	3·56
6 ,, ,, ...	3·39	3·76	5·49
Over 6 ,, ...	4·17	5·54	7·31

A cubic meter (35·3 cubic feet) of air-dried litter (15—20 % water) well compressed is of the following weight :—

	Kilos.	Lbs. per cubic foot.
Beech	81·5	5
Spruce	168·4	10·5
Scotch pine	117·3	7·3

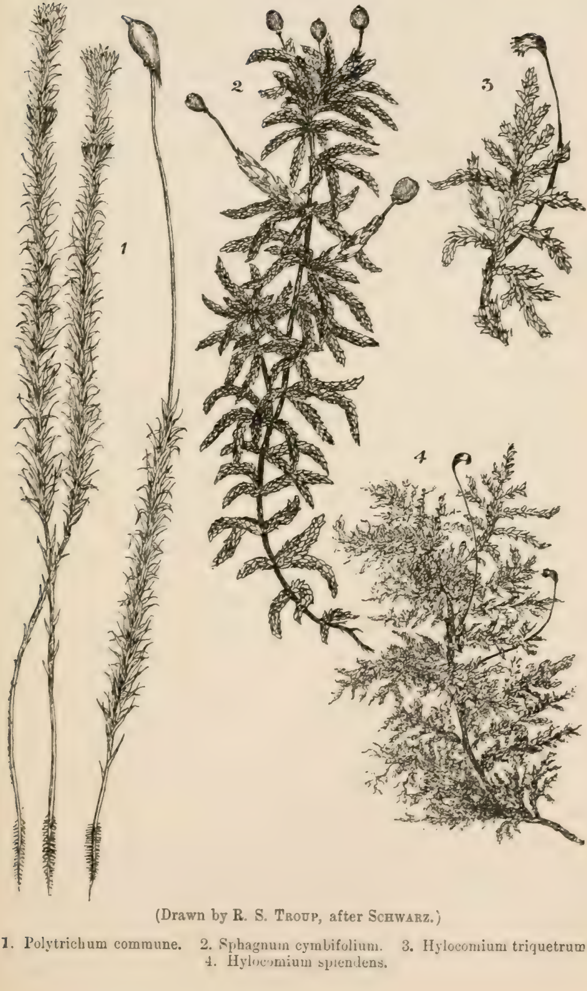
Hence the yield of litter may be calculated in stacked cubic meters or in waggon-loads per acre (as in the following statement) as waggons drawn by two horses usually carry 5 stacked cubic meters (176·5 cubic feet) of litter :—

	BEECH. Waggon-loads per acre.	SCOTCH PINE. Waggon-loads per acre.	SPRUCE. Waggon-loads per acre.
One year's supply	4	2·4	1·6
Six years' ,,	8	6·4	4·4

2. *Moss-Litter.*

The forest is the home of most mosses, and especially of the larger species which may be used for litter. The growth of moss generally depends on the presence of damp soil and air, and a certain amount of *cover*. Only a few mosses can stand full exposure to light. Some kinds of forest mosses only exceptionally form large tufts, whilst other gregarious mosses under favourable circumstances may carpet the ground over extensive areas. If these carpets are formed of the larger kinds of moss, they yield a very important form of litter.

Fig. 279a.



(Drawn by R. S. Troup, after Schwarz.)

1. Polytrichum commune. 2. Sphagnum cymbifolium. 3. Hylocomium triquetrum. 4. Hylocomium splendens.

Of the mosses usually employed for litter, several species of the large genus *Hypnum* and of other genera are common, as:*—*Hypnum Schreberi, purum, cuspidatum, molluscum, cupressiforme; Hylocomium splendens, squarrosum, triquetrum,* and *loreum; Brachythecium rutabulum; Campothecium lutescens; Thuidium tamariscinum* and *abietinum,* &c.; also *Polytrichum formosum* and *urnigerum; Dicranum scoparium; Bartramia fontana; Climatium dendroides;* on wet, swampy ground, besides some of the above, species of *Sphagnum* predominate.

The quantity of moss in a forest which may be used for litter, depends chiefly on the **species of tree** of which the standing crop is composed, the **age of the wood**, and the **system of management.**

As regards **species of tree,** moss is most prevalent in coniferous woods, and especially in those of spruce and silver-fir; it is rare for broad-leaved woods to produce moss in sufficient abundance to be utilizable as litter.

It is chiefly the annual fall of dead leaves in broad-leaved woods which forms an obstacle to the growth of moss, as they intercept the small amount of light which mosses require, and small tufts of moss which may be produced here and there are stifled by the dead leaves falling on them in succeeding years. It is different in coniferous woods: the thinner coating of dead needles affords room for the spread of any mosses which have germinated and sufficient light for their development. As the moss then grows regularly through the annual fall of needles, the litter consists of an inseparable mixture of moss and dead needles, and they can only exceptionally be collected separately.

In spruce and silver-fir forests, mosses receive not only a suitable degree of light, which is uniform during summer and winter, but also that high degree of moisture in the soil and air which is indispensable for their growth. In Scotch pine and larch woods, moss is generally an unimportant factor in the soil covering, or may be completely absent.

As regards **age,** in the early years of dense spruce and silver-fir forests there is only a slight production of moss; after the leaf-canopy has become elevated, so as to admit sufficient light to the soil and allow for a slight movement of air-currents, moss gradually spreads over the ground. It then continually becomes

* Vide Braithwaite's British Moss Flora; also James' Field-Flora of Mosses.

denser and deeper the higher the leaf canopy, and attains its maximum in mature woods which have been already thinned and contain *advance-growth*,[*] provided the soil continues moist.

The **system of management** affects the growth of moss, in so far that uneven-aged woods, resulting from natural regeneration by seed, are generally more favourable for the production of moss than even-aged and artificially formed woods.

Wherever the growth of moss is luxuriant, it regenerates itself after removal for litter more rapidly than under opposite conditions. If the moss has been completely removed, an interval of 3 to 5 years always passes before it is reproduced, and this may be longer on poor soils. Moss litter weighs about 6 lbs. per cubic foot (104 kilos per cubic meter).

3. *Litter from Weeds.*

The forest weeds which are chiefly used as litter are heather, broom, *Genista* and ferns: less frequently—bilberry-bushes (*Vaccinium Myrtillus*) and other species of *Vaccinium*, reeds, grass, &c.

Heather,[†] chiefly ling (*Calluna vulgaris*), flourishes only when fully exposed to light and on sour or heather soil which may be wet or dry. Any blanks or lightly-stocked places on sandy soil fulfil these conditions. Above all, sandy soil, poor in alkalis, with a sour humus and rich in carbon, is thoroughly conducive to a luxuriant crop of heather, which does not appear on mild moist forest humus. On such a soil, after waste lands plantations in lines are best suited for heather-litter, as the regeneration-areas are then most accessible, the production of the heather on such places where the soil has been loosened is good, and the removal of the heather is sometimes beneficial to the woody plants. Heather thrives on wet sour soil as well as on dry sand.[‡]

The present extensive development of heather in German forests is partly due to former defects in forest management, when the standing crop was kept too open, and extensive areas thinned for natural regeneration by seed had failed; also to the present system of clear-cutting, which, owing to the complete admission of light, has rendered the ground favourable for heather. Heather is, therefore, chiefly prevalent on sandstone formations, in regeneration-areas, blanks and in open woodlands; it is difficult to imagine a forest on sandy soil open to the removal of litter, without a rich crop of heather. Wherever for many decades heather has formed the sole vegetation, heather-soil accumulates to such a degree on the ground as almost to exclude all other plants and prevent the growth of most species of trees.

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[*] **Advance-growth.**—The seedling underwood springing-up in a high forest.

[†] In the New Forest, about 14,500 bundles are sold per annum at 1*s*. a 100 bundles, 6 bundles being about as much as a man can conveniently carry. Heather is also cut and sold in the Windsor Forest at 1*d*. a headload.

[‡] To see heather in perfection, the Landes of Gascony should be visited, there the shrubby heather (*Erica arborea*) grows vigorously with broom and other species to a height of 6 to 8 feet above the surface, and greatly exposes the Cluster pine-woods to conflagrations.

The **broom** (*Cytisus scoparius*) is produced by nearly every kind of soil; it is chiefly prevalent above sandstone and granite, but also grows on argillaceous schist, quartzite, limestone, and even on chalk. It always implies a fairly rich admixture of clay, and denotes a fairly rich soil. It resembles heather in requiring a complete exposure to light and a moderately warm atmosphere.

Broom is most abundant on blanks, in coniferous regeneration-areas, or in young oak-coppice. Owing to its somewhat exacting nature, broom is, in general, of subordinate importance as litter. [Largely used in the Ardennes.—Tr.]

Among **ferns**,[*] the widely-spread bracken (*Pteris aquilina*) is most important, *Nephrodium Filix-mas* and *Athyrium Filix-fœmina* are also used as litter. They require a moist, or even wet soil, but cannot stand stagnant moisture. Half-shaded localities, or exposed places, with moderate lateral light, suit them best.

They grow best in moist, no longer competely closed old woodlands, especially in spruce and silver-fir forests, with plenty of moss on the ground, or among uneven-aged patches of young woody growth; a complete leaf canopy hinders their growth. Clearings for plantations on a rich soil sometimes produce a vigorous growth of ferns.

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[*] [In the New Forest, the bracken is cut from the 25th September by Government Agency, and sold dried to farmers, who remove it from the forest, at 8s. a waggon-load, the cost of cutting and drying being 5s. In the enclosures it is much more patchy and costs 7s. a load to cut and dry, but is then cut and sold between the 1st August and 15th September at 15s. a load. People who are very keen about bracken being well-dried pay the extra price. From 1,800 to 2,000 waggon-loads are thus removed annually. In Windsor Forest, it is sold at 2s. a cart-load (one horse), the purchaser cutting it. In the Dean Forest, there is a poor crop of bracken, it being cut too early, which weakens the rhizomes considerably.—Tr.]

Bilberry-bushes, and other species of *Vaccinium* are less frequently used as litter than the above-mentioned plants; their stems are usually too woody, no weeds decomposing more slowly. They require a moderate amount of clay in the soil, and need shade in soils free from clay, and consequently dry.

Species of *Vaccinium* hence are found in loamy soil in lightly shaded old woods, when the soil has become superficially impoverished; more on warm than on cold aspects, both in broad-leaved and coniferous forests. A large suppy of *Vaccinium* litter, therefore, always implies deteriorating old woods, or stunted young woods containing blanks. On superior forest soils a vigorous growth of bilberry is also found in young woods not yet fully closed. The bilberry, like many other forest weeds, has a superficial root system, but no other weed covers the ground so thoroughly with its densely matted roots.* Hence results the superficial impoverishment of the soil, as far as the bilberry roots extend.

In wet, swampy localities, on fairly level ground, many species of **reeds and sedges** grow (*Juncus*, *Carex*, etc.); they have long broad leaves which die early in the winter, and can easily be raked together. In some districts, as in Upper Bavaria, meadows of sour grasses, rushes, etc., are used for litter.

Other forest weeds occasionally used as litter are of too rare occurrence to be mentioned here.

It is difficult to form an estimate of the amount of weed litter which an area may produce. This depends on the density and height of the weeds, and the mode of harvesting them. There is, for instance, a great difference between merely cutting the sappy tops of heather, or scraping up the whole plant with its roots. Similarly in harvesting broom or bilberry, the lower woody part of the plants may be more or less used. A roughly stacked cubic meter (35·3 cubic feet) of heather weighs about 60 kilos (3¾ lbs. a cubic foot), so that 2½ to 3 waggon-loads of heather, or 1¾ waggon-loads of broom, per acre, may be considered a good crop.

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* [Species of *Strobilanthes* have a similar habit in India, and most of them blossom only periodically, every 5 to 10 years. After blossoming, the whole crop dies, and thus allows tree seedlings to take root—otherwise an impossibility. Species of *Strobilanthes* are common in oak-forests in the Himalayas, but the genus is best represented in the Nilgheri Hills, where some kinds are largely used for fuel. Gamble, Indian Forester, vol. xiv., p. 153.—Tr.]

[From the New Forest, besides the litter from ferns and heather about 600 cart-loads of dead grass are sold annually at 1*s.* per load. Sedge-grass is also sold from Windsor Forest at 2*s.* a cart-load.—Tr.]

4. *Green Branches for Litter.*

In many districts the green branches of conifers are esteemed as litter. They are cut from standing as well as felled trees. In no kind of litter is the yield more variable, owing to the different ways in which the branches are cut. Its amount also varies with the species of tree, the system of management, the age of the woods, and especially with the question whether the branches are cut from mature trees nearly fit for felling, or from younger woods, and finally what amount of the crown of the trees is taken.

The amount of branch-litter depends in the first place on the **species of tree,** as the densely needled silver-fir can yield more litter than the spruce, and the latter more than the Scotch pine. Ramification in the silver-fir and spruce consists merely in small branches springing from the bole, whilst in Scotch pine the bole subdivides into boughs, so that besides having little foliage, the Scotch pine affords much branchwood which cannot be utilized as litter. The silver-fir and spruce have also far more twigs than the Scotch pine.

As regards **system of management,** selection-forest yields much more branch-litter than even-aged woods, and the use of branch-litter is chiefly confined to districts where selection-forests predominate. (The Tyrol, Swiss Alps, private forests in the Fichtelgebirge, Schwarzwald, &c.) There is much difference when branch-litter is taken from **mature trees ready for felling,** or a young pole-wood is thus utilized at regular intervals. Many Alpine forests have thus been rendered so unproductive as to be no longer capable of supplying even a moderate demand for branch-litter. In Franconia, the

Fichtelgebirge and some parts of the Schwarzwald, on the contrary, every peasant farmer has obtained yearly, from time immemorial, 1 to 1½ waggon-loads of branch-litter from his selection-woods, without any fear of reducing the crop. [Much branch-litter is used in the Himalaya districts.—Tr.]

The same **age of woods** which yields the greatest amount of ground-litter also produces most branch-litter; in dense even-aged spruce woods, from poles about 50 to 60 years old; in selection-forest, at an age approaching maturity. At the same time it should be noted that in utilizing branches in old woods, the ratio by weight of twigs utilizable to that of the woody branches useless for the purpose in question is as 1 to 3, in pole-woods 3 to 1, and in very young woods is even more favourable as regards stable-litter.

Section IV.—Modes of Harvesting Litter.

The different ways in which litter is harvested are all extremely simple, but differ according to the kind of litter in question.

1. *Litter from Dead Leaves and Needles.*

In collecting litter composed almost exclusively of dead leaves or needles, with only a few weeds and a scanty admixture of moss, wooden rakes are always used.

Iron rakes are quite inadmissible, as they not only damage the superficial roots of trees, but also penetrate the layer of humus, and which they partly remove, as well as litter. Thin layers of moss are also easily removed by wooden rakes. The heaps of dead leaves and needles are packed in cloths or nets for removal either to the farms or to a forest depot, where the litter is measured for sale, or carts are laden with it on the spot.

On smooth ground it is easy to rake up every leaf, but when the surface is uneven, interrupted by holes, hummocks, stones, rocks and roots, or overgrown with shrubs, bushes, grass or weeds, or finally, in places where swine have been rooting—raking is a difficult process. A considerable amount of litter which cannot be raked up is then preserved to the forest, and thus an indication afforded how the forests may be protected by artificial means against a too complete removal of litter.

2. *Litter from Weeds.*

Heather is the most productive form of weed-litter, and is harvested in different ways according to its age and sylvicultural requirements. Heather is usually cut with the sickle, provided it is not more than 3 to 4 years old; when old and woody, it must be cut with a strong knife, or whenever there is no fear of injuring forest plants which are growing among the heather, it may be pulled up by hand. Whenever the heather is harvested on blanks, or waste land, it is best to use a strong scythe, and when not only the heather but the grassy or mossy tufts which accompany it are utilized, a broad, sharp hoe is used. Bilberry and other *Vaccinium* undergrowth, also broom and ferns, when used for litter, are harvested like heather. All the heather and other weeds, which have been gathered are usually brought in cloths to the forest depot; broom and ferns are often firmly tied on the spot into bundles by means of withes.

3. *Litter from Green Branches.*

Green branches for use as litter are either cut from the standing trees, which men sometimes climb for the purpose, or are from felled stems.

The most destructive method of lopping branches, in use in parts of the Tyrol and Swiss Alps, is to cut them by means of an iron hook at the end of a long pole. In other regions men climb silver-fir trees by the help of climbing-irons, and use a short axe for lopping. Where this usage is practised in a conservative manner only trees shortly to be felled are lopped, within the space of a few years, beginning with the lower branches and then taking those higher up. If, however, no attention is paid to sylviculture, the trees are often lopped bare to the very top. The simplest and least hurtful practice is to lop the branches from felled trees on the felling-areas.

Coniferous branchwood, however it may be collected, is usually taken to the farms and cut into lengths on a block with a hatchet; all wood thicker than a finger is put aside for firewood and the rest used as litter. Wherever branchwood on the regular felling-areas is used for litter it may advantageously be bound up like faggots, the workman, before cutting the branches into the usual length of faggot-wood, cutting off the needle-bearing twigs from every branch with a bill-hook.

SECTION V.—EFFECTS OF THE REMOVAL OF LITTER.

Continuous removal of litter is prejudicial not only to the **vitality and productive power of forests**, but also to the **fertility and amenity of countries**, owing to the important action of forests on their physical conditions.

1. *Effects on Forests.*

(a) *Ground-litter.*

i. General effects.

When the soil-covering of litter and humus is allowed to decompose uninterruptedly, it returns to the forest soil the chemical elements of which it has been deprived, enriches it with carbon-dioxide and prepares it for absorbing and retaining all the nourishment requisite for the growth of trees; it maintains in the soil a suitable condition of porosity, admits moderate supplies of air, and finally, protects the soil against extremes of heat and cold. Nature has thus permanently supplied the soil not only with the materials but also with the forces necessary for the nutrition of trees. If these beneficial influences are withdrawn from the soil, circumstances are considerably altered. The soil becomes chemically poorer; owing to unimpeded evaporation it loses more and more that degree of moisture which is essential for the growth of trees; the supply of carbon-dioxide to the soil is greatly reduced, so that the process of forming humus and the consequent production of solvents for its mineral substances are arrested. In a word, the soil loses the power of producing trees, becomes dry, hard and dead, this eventually occurring even when a soil is chemically rich.

The soil of agricultural lands is partly an artificial product, being by artificial means rendered porous and well supplied with manure, water, &c.; forest soil, on the contrary, depends solely on the climate and tree-growth for maintaining its own productive powers, receiving nothing from outside; it must therefore be protected against the diminution or destruction of these powers, and this is only possible when the indispensable soil-covering of humus and litter is maintained.

If, however, the removal of litter changes the nature of the soil, the productive energy of its trees is impaired owing to bad nutrition. This is manifested either by a **reduction in the wood-increment**, or in the resulting impossibility of producing a certain species of tree, so that a **change in the standing crop** ensues.

(*a*) *Reduction of Wood-increment.*

In all forests from which the litter has been continuously removed, experience shows that the woods become more and more open and the crowns of the trees thin and spreading, whilst their height-growth and the annual wood-increment are reduced; the life of the trees is thus shortened and long rotations become impossible.

A chemically rich, moist and deep soil affords sufficient nourishment to trees in a small space; as soon, however, as the nutriment in the soil has been reduced, the tree requires more room, dominating stems crowd out their weaker neighbours by taking the nutriment formerly obtained by the latter and hence the woods become open. This opening of the woods causes other changes. The soil is no longer protected by a dense leaf-canopy, the wind and the sun's rays gain continually more access to the ground, which parts with its moisture and becomes still less nutritious, so that the growth of the trees is further impeded. It is chiefly the growth of the stem in height and thickness which suffers; thus on a soil weakened by the removal of litter the **arboreal growth** gradually loses its distinctive character and finally sinks to that of mere **scrub**, the development of branches gradually predominating over that of the stem. In this way the possibility of obtaining the most valuable forest produce is seriously impaired and the forest revenue consequently suffers, the woods yielding chiefly firewood and the proportion of branchwood and faggots continually increasing.

An organism, the vitality of which has been notably weakened, has a shorter life than one possessing full vital vigour; hence by the removal of litter the **rotation of woodland** is shortened. In vigorous forests, adapted to long rotations, the annual wood-increment remains steadily at its maximum for a long period, begins to decline only late in life and the woods continue to grow for a long time with a decreasing increment. Fertility and the production of seed are reached only at an advanced age. On the contrary, a wood, the productive power of which has been weakened by the removal of litter, attains only a poor increment, retains its maximum increment for a short period only, whilst its increment* frequently decreases rapidly. The rotation must therefore be reduced from time to time, the more quickly, the more unrestricted the removal of litter. Seed-production occurs much earlier, even when the wood is quite young, and, as in all weakly plants, is often very abundant.

(β) *Change in Species of Tree.*

A further effect of the removal of litter sometimes consists in the impossibility of producing any longer a species of tree which has hitherto been well-adapted to the locality. As long as local conditions remain unchanged, nature as a rule continues to produce the same species of trees, the existence and well-being of which depend, in any case, essentially on the effects of sylvicultural treatment and the degree of light admitted to a wood. If the productiveness of a soil is no longer sufficient for any particular species of tree, it must be replaced by one less exacting; the reverse being true where a locality has recovered its former fertility.

It is well-known that up to the commencement of the 18th century the forests of the lowlands, hilly tracts and central mountain-ranges of Germany were stocked chiefly with beech, oak, ash, sycamore, elms, &c., and only the sandy tracts near the sea, and the high mountains, with conifers. A great change has occurred; broad-leaved trees now only form one third of the German forest-crop, and conifers have replaced them in the lowlands. Although not the only cause of this change, the removal of litter from the forests is chiefly responsible for it. In innumerable places the soil has become so poor in nutritive substance and has lost so much of its former moisture, that species like the beech, oak, elm and silver-fir, which make certain demands on both these factors of fertility in soils, must yield the ground to less exacting trees. In many places, the spruce has replaced broad-leaved species, and a still larger area is now monopolised by the Scotch pine.

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* Vide the observations of von Krutzsch in the Tharandter Jahrbuch, vol. xv. p. 66.

[As regards the spruce, which being shallow-rooted requires a moist soil, the reason for its extension is the increasing demand for timber instead of firewood which is the chief product of beech-forests. —Tr.]

If the condition of the Scotch pine-woods which have replaced broad-leaved forest is further considered, it will be noted how even this non-exacting tree has suffered in vigour from continuous removal of litter.

Considering that the Scotch pine is the last member in our list of forest trees, once a Scotch pine-wood has been ruined by the removal of litter, there is an end of all forest vegetation. Thousands of acres of German forests are already at this final stage, where the Scotch pine, when 30 or 40 years old or even younger, either dies, or entirely ceases to grow; where its scanty crop of needles, its stunted growth, pigmy size and its bark coated with lichens almost conceal the fact that it is a tree. Unfortunately there are few German countries where such a picture is not to be found; it is hardly worth mentioning the names of forests in Brandenburg, in the pastured forests to the south-west of the Teutoberger forest, in the plateau of the Upper Palatinate, between Amberg and Regensburg, in the Nürnberg* State forest, on the whole mountain-range of the Haardtgebirge in the Rhine-valley, the Eifel and many other districts, which have thus earned a deplorable notoriety.

ii. According to special circumstances.

The above considerations show that in general the removal of litter not only weakens forest growth but may absolutely destroy it. These effects follow in very various degrees according to **locality, species and age of tree,** &c., and earlier or later, according to differences in these factors which must now be shortly discussed.

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* [The degraded condition of the Scotch pine near the city of Nürnberg is most pitiable, and it would be a national gain for Bavaria if the worst parts of this forest were cleared and converted into arable land, as heavy manuring would again fertilize the soil.—Tr.]

(α) *Locality.*

All localities possessing a comparatively high degree of moisture, owing to their position, altitude, configuration and aspect, suffer less than others from the removal of litter.

The removal of litter is therefore more prejudicial—on steep slopes, than on gentle inclines and level ground; on southerly and westerly aspects than on cool ones; on the higher parts of hill-sides; on ridges and hill-tops exposed to the wind; and less prejudicial on the lower parts of hill-sides, in valleys and sheltered places.

(β) *Soil.*

A chemically rich soil withstands the effects of the removal of litter longer than soils without the necessary amount of clay and lime. In the long run, however, such soils remain productive only when they are directly or indirectly supplied with continuous moisture, for the fertility of a soil is valuable only when it is sufficiently moist.

The nature of the sub-soil has considerable influence on the retentive powers of the soil for water; if the former should contain boulders, gravel, or deeply fissured rock, and the gradient be steep, all the moisture in the soil tends to descend to a depth* beyond the power of the forest to utilize it. As therefore the bad effects of the removal of litter are less felt on soils which are naturally moist, so also on deep soils, which allow the roots to penetrate deeply and obtain water from the subsoil. Nowhere are the bad effects of the removal of litter more disastrous than on a shallow soil above gravel, boulders, &c.

(γ) *Climate.*

Heat and a long growing period cause vigorous growth; this however, makes greater demands on the productive factors of the soil and especially on its moisture, and therefore the removal of litter is more injurious in warmer than in colder climates.

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* [In N. W. India, trees such as the Sal (*Shorea robusta*) and the Jhand (*Prosopis spicigera*), growing on deep and porous alluvial strata of a coarse character, which during the long dry season (October to July) may become dry to considerable depth, have sometimes tap-roots 20 to 40 feet long and even longer, so that they secure a water-supply even during the dry season.—Tr.]

Similarly, the removal of litter becomes less injurious the higher the altitude at which forests are situated.

(δ) *Species of Tree.*

No species of tree can of itself withstand the removal of litter better than any other; every species makes certain demands on the productive powers of a locality, and if the removal of litter interferes with its power of satisfying them, the vitality of the tree must be impaired. The susceptibility of any tree to injury by the removal of litter therefore depends only on the suitability of the locality for its growth.

For instance, if in a beech-wood, on a sufficiently moist and fertile loamy sand, the removal of litter is introduced, its bad results will ensue only after a long period of time; if, again, the usage be applied to a Scotch pine-wood on a sloping hillside with a poor sandy soil, which is liable to become dry, disastrous results may happen after a very few years, although the Scotch pine is less exacting than the beech. It may therefore be asserted that for any species of tree the removal of litter is less injurious, the better adapted the locality for the tree and the less its fertility is dependent on the soil-covering of litter and humus. The question is, therefore, purely one of locality, and will be differently answered for any change in the latter.

It should be noted that, for non-exacting species of trees, a larger area is suitable than for exacting species.

(ε) *Age of Woods.*

Removal of litter is most hurtful to thickets and young pole-woods, also to a wood in the period of maturity immediately preceding regeneration. Although there is less direct danger to high poles and trees, it cannot be said that they are uninjured by the practice.

In the case of **thickets** and other very young crops, the plants are chiefly rooted in the superficial soil-strata; all loss of nutritive matter from the removal of litter must therefore be severely felt.

In **mature woods** the demands on the soil are moderate, but the low vitality of the trees renders them liable to become stag-headed if the litter be removed. It should also be remembered that an old wood is the precursor of the future young generation, for which it has, as it were, to prepare the way ; in mature woods, therefore, the soil-covering should be as carefully preserved as in young woods.

The stage of **young pole-woods** is that of the greatest height-increment, which experience shows is greatly reduced when the soil deteriorates. There remain only the stages of **high-poles,** and of **trees which have attained their full height,** when the dense standing crop raises the fertility of the wood most markedly by preserving moisture in the soil and enriching it with dead leaves ; these are the only periods in which a moderate removal of litter is admissible, because the locality is then most able to afford the drain on its resources.

(ζ) *Condition of the Standing Crop.*

The remark has already been frequently made that vigorous dense woods in favourable localities can withstand the removal of litter far better than those under opposite conditions. Removal of litter is therefore most pernicious in all decadent, open and stunted woods. This applies to woods which have been devastated by **insects, snow, frost,** or abnormal **drought**; also, after any regular forest operations have been effected, such as **thinnings, fellings preparatory to natural regeneration by seed, selection-fellings,** &c. : woods are then more endangered by the removal of litter than at other times.

(η) *Amount of Litter Removed.*

It is obvious that the removal of litter is the more injurious the more frequently it recurs on the same area. The interval between two successive removals may be termed **close-time.**

The period during which the forest is closed to the removal of litter should evidently vary in different woods and at different ages of the same wood, if the amount of damage done is not to be excessive. The length of the close-time should depend on the **quality of the locality, species of tree** and **age of the wood.** The more susceptible a wood to danger from the removal of litter, in accordance with these factors, the longer the close-time should be.

The effects of removing litter differ also considerably, according as only the upper stratum of litter, produced during the current year and still undecomposed, is removed; or the lower strata of humus and mineral earth are raked up as well. The lower the rake goes, the deeper it penetrates the mineral soil and the more pernicious the practice.

If deep raking of the litter is frequently repeated, the soil dries up; when the soil is stiff, it becomes so compact and hard that, if the next year's supply of dead leaves is not blown away, it requires a long time to decompose and mingle with the soil. The forester should therefore permit the harvesting of only the upper layers of undecomposed dead leaves, and, in the case of a mossy soil-covering, should allow its removal only in strips or patches.

(θ) *Season for Removal of Litter.*

The removal of litter is most prejudicial during spring and summer; less so, in autumn, before the leaves fall; and, least of all, during the fall of the leaves.

In summer the soil requires most protection against evaporation of moisture, removal of litter during the hotter months is therefore very prejudicial; but if the soil-covering is removed in spring the soil will remain exposed throughout the summer, so that the harm done is then as great as in the former case. If, however, the harvesting is done just before leaf-fall, litter which has been lying decomposing on the ground for a whole year is removed, and, in order to obtain it in any considerable quantity, it is necessary to rake deep into the ground. It is, therefore, evidently best to remove litter in autumn **during the actual fall of the leaves.** Then it is quite possible to leave part of the decomposing litter and of the fresh supply of dead leaves on the ground.

(ι) *Statistics.*

All the above remarks regarding the effects of the removal of litter result from the multifarious and prolonged experience of foresters. They are also supported by observations made in many places, regarding the direct loss of wood-increment from continuous removal of litter.

The careful observations made by Dr. Bleuel,* on experimental forest areas in Bavaria, are extremely valuable. He states that by annual removal of litter for 23 to 30 years in older beech-woods, the wood-increment fell in different cases by 32, 39, 42, and even 56%, on inferior soils; but that on good basalt, in the Rhone-valley, the loss was only 8%. In Scotch pine-woods of good quality the loss where the litter was removed annually, was 7·5, 9·3 and 10·9%; where it was utilized every three years, in beech-woods in the Spessart, 13%, and when utilized every six years, 10%. These observations thoroughly prove that the loss of increment continues to increase with the number of years during which the litter is utilized.

(b) **Effects of using Branch-litter.**

The importance of the use of branch-litter should be considered from three points of view. In the first place, needles are organs of nutrition and any considerable reduction in their number tends to starve the trees. Secondly, young shoots are richest in ash-constituents. Even leafless twigs, especially when furnished with numerous buds, contain nearly as large a percentage of ash as the foliage. By lopping the crowns of trees it is evident that the material for forming ground-litter and humus is diminished. Wherever the soil requires litter to render it productive, persistent lopping must be as injurious as removal of ground-litter. Finally, stems which have been lopped, when sawn, yield inferior planking with loose knots.

Lopping branches for litter is therefore injurious to woods which are intended to remain standing. The usage is least injurious in mature age-classes of spruce and silver-fir, if practised with moderation late in the winter and care is taken that the least possible amount of injury is done to the standing crop. There is no harm in thus utilizing the branches of felled trees on regular felling-areas.

The dense crowns of spruce and silver-fir can stand lopping better than the thin crowns of Scotch pine, the more so that the soil in the former case is covered with moss, which is usually absent from Scotch pine and larch woods. If woods about to be regenerated or under regeneration are lopped, no harm can result ; in fact the process of natural regeneration may be thus furthered. Lopping becomes destructive whenever it is done throughout the life of a wood, even if only after intervals of 10 years. Many woods in the Tyrol, the Salzkammergut, Steiermark, &c., afford sad proof of this.

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* Influence of the removal of litter on the production of wood in the Spessart beech forest, Würzburg, 1890. Further works by the same author, regarding forests in the Rhone-valley, the Steigerwald, &c.

The degree of intensity of the lopping may evidently vary greatly. The amount of injury done depends on the age of the trees, the density of the wood and especially on the nature of the locality. The younger the woods the more restricted should be the lopping. State regulations of 1839 in the Tyrol allowed, on payment, lopping of stems 3 inches thick at the base! There can be no doubt as to the different effects when trees are lopped every year, or only after a longer or shorter interval of time. In the Tyrol, lopping is considered admissible with a close-time of 6 years, commencing when the woods are 30 years old and up to the age of 60 years, but the practice is confined to lower branches which would shortly become dry.

The **season** in which lopping is allowed is of importance, for summer is evidently the worst season, and the practice must be restricted to the season of non-growth during winter and early spring.

As regards the **mode of lopping**, it is evidently better to cut the branches clean from the stem and leave no snags : this is best done with the saw, and in careful lopping only this instrument should be used. Usually, however, the axe is employed, much damage being thus caused, which results in rot and the flow of resin. The worst practice of all is when an iron hook at the end of a long pole is used to tear the branches from the stems. Many woods of spruce, larch, and other trees in the Tyrol have thus been completely ruined.

2. *General Physical Effects of the Removal of Forest Litter.*

At the commencement of this chapter reference has been made to the fact that litter and humus retain a considerable amount of water. Water reaching the ground in the form of rain, dew and snow, is chiefly retained by the litter and humus, whence part of it penetrates into the layer of soil occupied by the roots of the trees, and part of it is evaporated into the lower strata of the atmosphere. **The soil-covering of litter therefore forms a permanent water-reservoir** which is never completely dry, and is constantly supplying springs with water. Forest moss in particular retains large quantities of water; it absorbs the heaviest falls of rain, so that the casual observer can hardly imagine what has become of the water.

If mountain-slopes are deprived of litter, the soil being exposed by the sun's rays or merely slightly covered, atmospheric precipitations are not retained; very little water penetrates into the hardened soil, most of it running down into the valleys. The numerous mountain-rills of water unite in a few hours time into overflowing mountain-torrents, which carry destruction down to the villages below. The steeper the mountain-slopes, and the more abrupt the descent of the rills, the more rapidly does the water collect and the greater its force; the loose transportable forest soil is carried down into the valleys, permanent water-courses are formed in the mountain-sides, which, after a few years, become deep ravines and constantly encroach on the surrounding land. The rapidly accumulating water often forms a powerful torrent and carries down sand, gravel, stones, rocks, in fact every thing in its path, to the agricultural lands below. This erosion is most destructive on steep limestone and sandstone formations, and in many countries every storm of rain or rapid melting of the snow causes the greatest anxiety (as in the Eifel, Aarthal, Haardtgebirge, Franconia, Tyrolese and Swiss Alps, Rhone-valley, &c.).

When once a forest has lost its soil-covering of litter, moss and humus, it has practically lost all its natural utility to the welfare of a country; for this chiefly consists in a uniform distribution of the yearly atmospheric precipitations. Countries where the mountain-forests have been destroyed are more and more exposed to ruin by floods. Whatever damage may have been caused in certain cases by the clearance of forests, is as certainly effected in forest districts where the pest of excessive removal of litter is permitted. These effects are merely the precursors of the complete disappearance of forests, and those who erroneously allow such an interference with the laws of Nature will soon realise how she avenges herself.

SECTION VI.—VALUE OF FOREST LITTER FOR AGRICULTURE.

The very existence ot agriculture depends on a sufficient supply of manure. Both agricultural and forest land require that all soil-constituents which the crops have taken from them —in fact their own ash-constituents—should be restored, or they will become sterile. In order to meet the constantly increasing demands on the soil made by agricultural crops, every farmer nowadays, besides using imported artificial manure, endeavours as much as possible to increase the supply from his own farmyard. In order, however, to obtain more farmyard manure, more fodder-crops must be grown, and any scarcity of hay, clover, &c., must be met by using straw. But stalled cattle require litter partly to afford them dry bedding, and partly for the absorption of their excreta; when therefore there is not sufficient straw for this purpose, a substitute may be found in dead forest leaves, needles and weeds. There are in Germany many farms where all the straw is used for fodder, or sold, and only forest litter used for bedding. Hence during the present century the belief has spread, that forest litter is more or less indispensable for the farmer, and the forest owner is practically obliged to supply it.

The questions must therefore be discussed, first, what is the agricultural value of the different kinds of forest litter; and secondly, under what circumstances forest litter is a real necessity for agriculture.

1. *Agricultural value of Forest Litter.*

The agricultural value of the different kinds of forest litter depends on their value as manure, and as material for bedding. Some other factors are also important, such as the comparative rapidity with which they decompose, their effect in rendering soil porous, &c.

The amount of contained ash-constituents (phosphoric acid, potash, &c.) and of nitrogenous compounds decide the manurial value of forest litter. All forest litter, except ferns, is poorer than straw in ash-constituents. The observations of Wolff and Ebermayer* as regards the percentages of mineral constituents in the ash of forest litter are given below:—

Kind of Litter.	Potash.	Phosphoric Acid.
Ferns and rushes	22—24	5—6
Different kinds of straw	7—11	2
Moss and Broom	5½—6½	1½—3
Dead leaves	3	3
,, needles	1½—2½	1—2½

Forest litter is sometimes richer in nitrogenous matter than straw. It is, however, much more valuable as **bedding material** than for its intrinsic manurial value. Good bedding material should readily absorb and retain the excreta of farm animals. With the exception of dry moss and peat, all other forms of forest litter are inferior to straw in this respect. Leaf litter and dead ferns come next to these in value, while coniferous needles and heather are less suitable. The absorptive power of weeds and branch litter varies inversely with their more or less woody nature.

[Ebermayer states that animal manure containing much ammonia has a basic action; vegetable debris, except when mixed with lime or ashes, is acid.—Tr.]

The **absolute value** of the different kinds of forest litter depends chiefly on their value as manure and bedding, but, as noted above, other factors also intervene. Taking all these into consideration, the different kinds of litter may be classed as follows:—

1. **Moss**, either alone, or mixed with needles.
2. **Wheat-straw.**
3. **Dead ferns.**
4. **Dead leaves**, of beech, sycamore, lime, alder, and hazel.
5. **Coniferous needles**, and dead leaves of species not included in 4.
6. **Weeds and branch-litter.**

Moss, when used dry, is the best of all forest litter; it is more absorptive than straw, and contains more nitrogenous matter, phosphoric acid, and potash. Its rate of decomposition varies with the species of moss. Mosses which usually occur in spruce and silver-fir forest become rapidly converted into a fairly light soil; the more fibrous kinds of moss, which grow on swampy ground, decompose more slowly.

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* Die gesammte Lehre der Waldstreu, p. 109.

Dead ferns also form a valuable kind of litter, containing not only the largest quantity of ash, but also, when thoroughly dry, being highly absorptive of liquid manure. Ferns also rot rapidly, and improve the porosity of a soil.

Litter of dead leaves of beech, lime, sycamore and hazel is very nearly as valuable as straw; when used for manure, however, unless thoroughly rotten, it is rather harmful to light soils, in which it forms stratified layers, does not decompose uniformly and often renders the soil too loose. Thus, light, sandy soils manured with it often become superficially dry, and the leaves and dung applied to them are blown about by the wind.

Dead needles, taken alone, are inferior to dead leaves of broad-leaved trees, both in their ash-constituents and power of absorbing dung. As, however, there is generally a certain amount of moss with the needles, this increases their value as litter, and hence, a mixture of dead needles and moss is preferred to dead leaves.

The **branches of conifers** form a litter very variable in value. If it contains only the twigs and last year's sappy shoots of the trees, and all woody pieces less than the little finger in thickness are carefully excluded, this litter in many districts is considered valuable for stiff soils. It is not used in loose, sandy soils, or when very woody.

Heather, as well as litter from other weeds, is agriculturally inferior to the kinds already referred to. It varies, however, in value, according as only the upper half of the plants, or the whole plant is used; if cut when young, or when old and woody; in the spring, or the autumn. Sods of heather, including the roots and humus around them, as well as the whole plant, are much more absorptive of dung than the heather alone; but their removal is never permissible under careful forest management.

2. *Cases where Forest Litter is Indispensable for Agriculture.*

The condition of agriculture is so variable in different countries, and the intensity with which land is farmed differs so considerably even in one and the same district, that to answer the above question requires a special consideration of each case. The main factors of general application are;—the **natural productiveness of the soil, climate and season, area of farms, density of population** and **comparative knowledge of agriculture** by the farmers. If any special case is considered under each of the above heads, a decision may be formed as to the indispensability or otherwise of forest litter.

Within certain well-defined limits forest litter may be considered indispensable to agriculture:—in the case of **inferior soils** and **unfavourable climates**; in years of **scarcity of straw and fodder**; **in over-populated districts** where landed property is much subdivided and garden-husbandry or the cultivation of potatoes extensively followed; or where, in fairly productive localities, the **land is being over-cropped.**

In all other cases, and especially where bad farming prevails, and the farmer from obstinacy and indolence declines to adopt improved agricultural methods, there can be no real necessity for concessions of forest litter.

This is a question which must be considered from both points of view, that of the forester as well as the farmer. To the former, the removal of litter may involve the destruction of his forest, and he is clearly entitled to ask whether the farmer has thoroughly utilized all the resources of his land before making demands on the forest, for experience shows that he is justified in mistrusting the statements of the ordinary farmer as to the actual necessity of litter for his land. It is also a well-established fact that many officials and authorities on agriculture adopt very one-sided views on this question, attaching little importance to the maintenance of forests, whilst they make no really serious efforts to improve agricultural practice. Provided, therefore, the opinion of unbiassed experts has not been expressed in favour of an increased concession of litter, forest officials, who can easily acquaint themselves with the local bearings of any case, should deal with every application for forest litter on its own merits.

Bad soils and unfavourable climates are not insuperable hindrances to profitable agriculture; on the other hand, places where agriculture is contending with forestry for the land, mountain-forest regions and extensive sandy plains only penuriously repay the most assiduous industry of the peasantry. There is no more erroneous State policy than that of sacrificing forests to the plough in places where Nature denies the means for profitable agriculture. Agriculture will never prosper on actual forest land or on soil naturally adapted for forests. Unfortunately farms have been extended into real forest land, the complaisant forest owner having thus prepared a rod for his own back, and he cannot now refuse moderate concessions of forest litter to the farmers.

Over-population and excessive subdivision of landed property are cankers in agriculture against which the forester is powerless. In such cases, the forest is invariably sacrificed, for there can then be no question regarding the actual necessity for forest litter, but only how to maintain the forest in spite of its removal.

During years when crops have failed and the supply of straw and fodder is below the average, the scarcity of straw being everywhere felt, it is fully justifiable, as an exceptional measure, to meet the deficiency from the forest. Thus, in the year of drought 1893, 75,000 tons of forest litter were conceded from the Bavarian State forests. A careful inquiry must, however, first be made as to the existence of such a scarcity, for the farmer is always poor until one sees his banking account. Even when necessity has been proved in any year, forest litter should only be conceded to those actually requiring it, and in accordance with the provisions of Section VII. of this chapter. Obviously, when concessions of forest litter are made, the supplies of litter to right-holders must not be reduced, neither can any prescriptive right arise from such exceptional cases due to the temporary necessities of agriculture.

No agricultural crop makes greater demands on the soil, or requires more manure or more quickly acting manure, than the vine. Vineyards are commonly found in localities where landed property is much subdivided, so that farmers can only obtain a living by growing a highly valuable product which fully employs all their labour. Whenever, therefore, a vineyard is grown outside the natural zone of the vine, it is an unjustifiable intruder, which can make no possible claim for external support, —in other cases, however, vineyards require forest litter and can only with difficulty dispense with this assistance. The cultivation of tobacco, beet-root for sugar and other similar crops not used for household consumption, and intensive market-gardening, are similarly situated.

Indolence, obstinacy, blind attachment to long usage and want of receptivity for good advice on the part of a peasantry are the greatest hindrances to success in agriculture. Farmers find it easier to claim assistance from forests than to obtain what their land requires by their own exertions: they are not sufficiently ready to improve their farms—by increasing the area of good meadow-land; growing green fodder-crops; deep ploughing; changing the rotation of their crops; reducing an excessive stock of cattle, which may at present yield them much manure but of bad quality; making better dung-heaps; saving liquid manure, also by a more extensive use of artificial manure and of substitutes for straw. Among the latter are—material obtained from swampy meadows (rushes, reeds and coarse herbage); sawdust, which is produced in enormous quantity at saw-mills; forest weeds, and finally, peat-litter* which may be obtained almost everywhere and has proved extremely useful, and wood-wool which is very cheap in Germany.

Several means are thus at the disposal of the farmer for improving his position, without using forest litter, which he has hitherto considered indispensable. It is, however, difficult to teach him improved farming, except by the stress of necessity; this hard master should therefore be employed to his own advantage and that of the forest, whenever he indolently wastes his own resources and tries to live on the ruin of forests.

Forest litter is not necessary, and should always be refused, when farms show signs of wasteful management. This waste is chiefly shewn when stall-manure is wastefully collected and used, and its liquid parts allowed to drain away. The forester is always justified in enquiring whether the cultivator has done his duty, before applying for assistance. Were the farmer always to calculate the cost of a waggon-load of forest litter, including royalty and cost of cutting, collecting and carriage, he would generally discover that straw or peat-litter is as cheaply obtainable.

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* [Largely used in London stables, being imported from Holland. Vide ch. iv. part iii. of the present book.—Tr.]

[One of the chief kinds of forest litter in the Bombay Presidency of India, is termed **rab**, which means gathering inferior bamboos, branches and vegetation of all kinds and burning it in heaps, on the rice-fields. In some districts, ráb is applied only to the nurseries of young rice-plants, which are covered with successive layers of dung, grass, bushes and pulverised earth and finally with grass. This is then burned and dug into the ground.*—Tr.]

SECTION VII.—LIMITS TO THE PERMISSIBLE USE OF FOREST LITTER.

1. *General Account.*

Although there is no reason to despair of overcoming the practice of using forest litter in districts where it is everywhere prevalent or prevails to an intolerable degree, or at least of freeing State forests from this burden, it is out of the question to think of any immediate abolition of the usage. The more therefore it threatens the existence of forests, the more carefully should the latter be treated from all points of view. Although a vigorous forest can withstand sylvicultural mistakes and other dangers better than another forest in a less promising locality, nowhere are the bad results of erroneous management more severely felt than in a forest exposed to intensive removal of litter. Wherever symptoms of impoverishment of soil are noticed, a forest should be most carefully managed. Protection of the soil should then be aimed at rather than production of wood in quantity or quality, for the soil is the best implement the forester can employ, and this he should never forget. Not that any sylvicultural measures can annul the bad results of the removal of litter, but these results become worse when forest management neglects to take into account the reduced productivity and care-demanding nature of the soil.

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* Vide Baden Powell, Forest Law, pp. 336 and 361. Bradbury, Agnew & Co. London, 1893.

Maintenance of a dense leaf-canopy should be the chief maxim; it cannot indeed be expected that the standing-crop will be as dense where litter is removed as in an unimpaired forest, but this failing need not be increased by defective sylvicultural treatment. Thinnings and extraction of dead trees should be discontinued in such cases, unless a proper control is exercised over woodcutters, who are inclined to imagine that they can find dead trees all over a forest. Great care should be exercised in thinnings where litter is removed, for the peasantry prefer these fellings to any others, as they yield wood without any reduction of the area from which litter may be obtained. The forester should, however, most carefully attend to his mature woods, to compartments opened out by fellings, and secure their regeneration as soon as possible. Some of the following protective measures should be adopted, according to the circumstances of the case:—Soil-protection woods; protective-belts of spruce in places exposed to the action of winds; abolition of the removal of dead wood; maintenance of water-reservoirs in mountain regions, and utilization of the water to irrigate the hill-sides; in any case, great caution should be shown before draining plateaux in mountain-regions, and, as a rule, such drainage should not be undertaken; horizontal trenches should be dug on steep slopes for the retention of dead leaves and water, as in the Bavarian Palatinate; slopes, whence litter has been removed, should be roughly hoed with the same object.

Although the forester can do something sylviculturally to protect the soil of the forest, more may be done by the method under which the litter is removed. This must obviously be rendered as innocuous as possible; thus the demand for litter should, if possible, be met by supplying those kinds which the forest can best dispense with; places and woods are opened which can best withstand the loss; the intensity and length of rotation of the removal of litter should be modified in places which are most liable to injury, and a season chosen for the usage when the soil is least exposed to be dried up.

2. *Kind of Litter.*

Litter from roads, halting-places, ditches and blanks, and from forest weeds, may be supplied with least injury to the forest. Clear-cut areas yield the greatest amount of weeds, especially heather, which may be injurious to young forest plants. If weeds are used, and only their tops cut their lower parts being left in the ground, so that the soil-covering of moss, dead leaves, &c., is undisturbed, this mode of removal of litter may be considered innocuous.

Heather should not, however, be pulled up by the roots, and certainly not hoed up in sods. Steep slopes should, as far as possible, be protected from this mode of removal. The removal of branch-litter from felling-areas also does little harm, whilst lopping branches from mature trees may be practised when subject to strict sylvicultural rules. Wherever branch-litter is used, ground-litter must be scrupulously preserved. Only when other sources of supply fail should the removal of ground-litter be permitted from the woods. The remaining paragraphs refer to that mode of litter only.

3. *Locality.*

The better localities should be first taken in hand, the inferior ones being spared as long as possible. Litter which has been heaped up by the wind in wet places, on moist, low-lying ground, in hollows, ravines or narrow valleys, and thick cushions of moss in damp ground and on places about to be regenerated naturally, may be utilized with the least damage to the forest. There is sometimes in cold localities a stiff, heavy soil, which is improved by removing the litter. The north and east slopes of hills, with rich deep soil covered with scattered blocks of stone or boulders, and terraces or gentle slopes on mountain-sides, should always be preferred, the more exposed places being only used as a last resort. Places exposed to wind, such as hill-tops, mountain-ridges, steep declivities and especially the upper parts of steep mountain-chains, should always be spared.

4. *Nature of Forest.*

As regards species of tree, the only question to be considered is whether or not a tree is suited to the locality. Wherever in alder- or birch-woods the usage is possible, it may always be permitted, also among pollards and in forests open to pasture;

in all other kinds of forest the question should be decided according to the nature of the locality. All woods which are deteriorating for any reason—which have suffered from caterpillars, snow-break, wind-break, drought, &c., or in which, from any cause, the leaf-canopy has opened out—(for instance, immediately after thinnings, preparatory fellings, &c.)—must be protected as long as possible against the removal of litter. Even-aged old woods ready for felling, and all young woods till they have reached middle-age, should in any case be spared. Litter should, as far as possible, be carefully preserved in coppice-with-standards and coppice, and especially in oak-bark coppice.

5. *Intensity of the Usage.*

Only undecomposed litter should be removed, that in process of decomposition being preserved. This proviso cannot indeed be completely secured, but every effort must be made in this direction and the removal of the humus should never be permitted. The more a locality requires protection, the more superficial should be the removal of the litter ; this is possible if the workmen are engaged by the forest manager, but when the peasants remove litter on their own account, it is better to allot a large area instead of a small one for the removal of litter. The mossy carpet in spruce and silver-fir forests should never be entirely removed, but only in patches or strips. The hoe must never be used for removing heather in sods. When dead leaves are raked together, only a wooden rake with wide intervals between the teeth should be used, never an iron rake.

6. *Length of Close-time.*

The length of close-time between two successive removals of litter from the same area depends on the nature of the locality ; the soil and configuration of the ground should be considered first, and, only in the second place, the species, age, and condition of the wood. It requires no argument to prove that the forester should insist on as long a close-time as possible, and should only consent to an interval less than 6 years when absolutely compelled to do so. The close-time may be shortened in woods of high poles or of trees which have attained the full height, but must be kept as long as possible in the case of younger or older woods. No rigid interval should therefore be adopted for close-time, but its length should vary according to variation in the locality or the condition of the woods.

7. *Season.*

Heather and broom should be harvested just before they are completely in blossom, ferns* in the autumn; on regeneration-areas it is better to collect litter somewhat late in the year. Branch-litter must be lopped in autumn and winter only. Ground-litter should be raked up chiefly in autumn, while the leaves are falling. Wherever the removal of litter must take place in spring, it should be restricted as much as possible in quantity; the farmer, however, requires more litter in spring than in autumn. Dry weather is preferable for the removal of litter as the work is then less laborious, and because, in wet weather, in order to obtain dry litter, the peasant will select those very places which are most liable to damage.

8. *Plan of Operations.*

It is in many places usual to draw up a plan of operations for the removal of litter, to serve for a longer or shorter series of years; this is usually revised at the same time as the forest working plan. In such a plan all compartments are designated which may be opened for the removal of litter, subject to a suitable close-time, and the plan is based on area. Although this plan is drawn up on different principles in the different German countries, yet they all agree in excluding from the usage areas requiring protection, and especially all kinds of young woods. After this is deducted, the remaining area is divided by the figure representing the rotation of the litter, the quotient being area which is opened annually for the removal of litter. In order to compensate for the withdrawal of the annual felling-areas from the area open to the removal of litter, an area of the oldest woods equal to those which were closed, must be opened annually to the usage. In countries where years of scarcity of straw occur periodically, a reserved area of woodland should be set aside, which may be opened when required.

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* Hon. G. Lascelles, Deputy Surveyor, New Forest, states that if bracken is cut before the end of September, as in the forest of Dean, its rhizomes become greatly weakened, and the crop becomes gradually poorer.—Tr.]

In Baden, removal of litter is not allowed in the case of broad-leaved woods, till they are 40 years old; in coniferous woods—30 years and in coppices—12 to 15 years. The shortest close time is one year. In Hesse, removal of litter is not allowed in high forest till after the first thinning, and in coppice till the second half of the rotation. In Bavaria, all woods are closed to the removal of litter till the second half of the rotation; the close-time is as follows:—

Nature of Forest.	Moist soil.	Dry soil.
	Years.	Years.
Scotch pine, larch, birch …………	2	5
Beech, oak, silver-fir, spruce ……	5	9

In the Württemberg State forests all rights to litter have either been commuted [by purchase, or by granting a forest area to the commune which held the right.—Tr.], or are now in process of commutation, so that no plan of operations for the removal of litter is required. In Prussia the local forest official is authorised, according to the actual requirements of the people, to open those forest areas for the removal of litter which are best able to bear it.

Wherever removal of litter has gone too far and especially in the case of prescriptive rights to litter, plans of operation for its removal are extremely valuable, as they represent the extreme limit up to which the usage may be practised, though they often go too far in this direction. Wherever there is no absolute necessity for the usage, it is better not to draw up such a plan; for this is apt to prevent any interference with the removal of litter by fostering the belief that the plan must be completely carried out. A custom then arises among the people of using the full amount of litter the plan may allow.

In putting such a plan in practice the forester should not actually open the whole annual area allotted by the plan, but only so much as experience shows is actually required, *i.e.*, the litter should not only be granted by area, but also by volume.

SECTION VIII.—MODE OF DISPOSAL AND SALE OF FOREST LITTER.

1. *Persons who may Remove Litter.*

Owing to the great prejudice to wood-production caused by the removal of litter, this usage is not considered as a regular form of forest utilization, as in the case of wood and other minor produce; but unless there is any actual right of user, it should only be permitted as an **extraordinary concession for otherwise irremediable agricultural distress.** Thus litter is only granted by a forest official to right-holders, or by special permit. In either case the amount granted is limited by sylvicultural requirements, as laid down for instance in the plan of operations, and in cases of urgent necessity even these may be exceeded.

(a) **Right-holders.**—Rights to litter are generally unlimited in amount; even then they must be limited by the requirements of the right-holders, or by those of sylviculture. It is extremely difficult to decide what are the actual requirements of the right-holders, so that sylvicultural requirements must be paramount. All national-economic laws in Germany prescribe that rights to minor produce from a forest must be so limited in volume as not to endanger the production of wood. The necessary limits are laid down in the plans of operation for litter which have been drawn up by competent persons, and all grants of litter to right-holders must therefore be kept within the limits prescribed in these plans.

(b) **Permit-holders.**—Permits to remove litter should be given only to persons actually in need of it. No peasant who wastes manure, who keeps no cattle, who is not a cultivator, who does not use available substitutes for litter, who uses forest litter in a wasteful manner, who sells or disposes of forest litter to other people, should on any account receive permission to remove litter.

2. *Sale of Litter.*

Litter can be sold only in two ways; by **royalty**, or by **public auction.** The latter method, however, is not generally applicable, as litter should be regarded as only extraordinary forest produce, the price for which is fixed by the forest official and not by competition; at any rate, leaf, needle and moss-litter should be sold by royalty and not by public auction.

If litter is sold to the highest bidder, it at once assumes the character of ordinary forest produce; farmers base their cultivation on these sales and expect them to recur annually, and thus a steady demand for litter arises.

The value of litter depends on agricultural requirements only, but in fixing the royalty for it, foresters will also consider the damage caused to forests. Large land-owners and wasteful farmers do not need forest litter, and only necessitous peasants should obtain it; but when sold to the highest bidder, the latter class may not be able to compete for it with the farmer. Several methods have been adopted to enable the poorer peasants to compete with the better class of farmers in these sales; the best known of these has been practised in communal forests in Hesse since 1839: the litter is collected under the forest manager's control and sold to the highest bidder and the money thus obtained divided amongst the inhabitants of the communes.

There is, however, little or no objection to auctioning litter of forest weeds or branches, the removal of which rarely injures a forest. The agricultural value of these kinds of litter, therefore, is mainly in question and they may be sold annually to the highest bidder.

In fixing royalties for litter, two points must be considered, the unit of measurement to be adopted and the rate of royalty.

(a) **Unit of measurement.**—Forest litter may be measured by area, or volume; in the former case, as a rule, one or more compartments in a forest are opened to all permit-holders who remove the litter collectively. They then either divide the litter amongst themselves, or each permit-holder is allowed to remove a specified number of cart-loads or head-loads. Separate areas are then usually allotted to the different modes of conveyance (carts, wheelbarrows, head-loads, &c.).

When the litter is disposed of by volume, heaps of specified dimensions are usually prepared by the permit-holders. The size of each heap usually corresponds to the local waggon-load, (for two horses or bullocks) termed in German (*Fuder*), being equal to five stacked cubic meters.

The disposal of litter by area, where everyone may take as much as he can collect, is least advisable; it gives too great advantage to farmers with good teams and numerous labourers over needy peasants, and the surface of the ground is usually scraped so clean of litter, that it is completely deprived for a long time of its humus. In order to protect the forest from such a calamity, large areas are opened at once, so that it is impossible to remove all the litter on them within the prescribed time. Even when a stipulated number of cart-loads, barrow-loads, &c. is prescribed, the ground is not protected from excessive removal of litter, for the permit-holders always endeavour to collect their litter from off the smallest possible area, so as to reduce the labour of collecting it.

Removal by volume in heaps is therefore preferable to the former method, and does less injury to the forest. The litter is then brought alongside the roads and piled in heaps as rectangular as possible, these are counted and delivered in a regular manner to the permit-holders. It is a pity, that this regular method of distribution, which prevails for all other classes of forest produce, is not the rule for litter where sylvicultural requirements are so urgent. The fact that the collectors are right-holders is no obstacle to the enforcement of this system.

(b) **Price of litter.**—Strictly speaking, the price of litter should depend on the loss of wood-increment caused by its removal; for, from a sylvicultural point of view, litter is as valuable as the additional volume of wood which would grow on an area, were the litter allowed to remain. Since, however, the exact amount of the loss of wood for any locality can be determined only by long repeated observations, and in many cases is non-ascertainable as a rule, this method of valuing litter must be abandoned.* Another means for determining the royalty on litter is its agricultural value, which should be the minimum royalty for litter, and may be most correctly determined by selling it by public auction. The agricultural value of litter is, however, also measured by the current price of straw, and the royalty should unhesitatingly be placed at this figure, after deducting the cost of collection and removal of the litter.

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* Vide p. 613, where Dr. Bleuel's observations are given, which afford the most correct basis for valuing litter.

It is of the highest importance that a proper royalty for litter should be fixed. Formerly, in many districts, litter was given either free, or a small charge levied in order to protect the forest against the usage becoming a prescriptive right, which scarcely interfered with the gratis character of its delivery. When, however, any produce is given gratis, the presumption is that its owner sets no value on it. Forest-owners could not therefore complain of the widespread idea that litter had no sylvicultural value.

Such an important item in forest production, without which a steady yield of wood is scarcely conceivable on forest soil often absolutely poor in itself, should, if sold at all, be sold at the highest price obtainable. If forest litter is of such essential importance to agriculture as people imagine, it should certainly be sold, and at the same rate as straw, for it is a matter of everyday experience, wherever forest litter is used, that straw ceases to be used for stall-litter, and consequently forest litter is a complete substitute for it.

Even in cases where forest-owners for certain reasons are compelled temporarily to facilitate the removal of forest litter, it should not be given gratis, though lower prices than those current for straw may be charged. This position among others was adopted by the Bavarian Forest Department in the year of drought 1893–94.

CHAPTER VIII.

RESIN-TAPPING.

[IN Germany, only the spruce is tapped for resin, and though this practice was formerly carried on in all extensive German spruce forests, it is now becoming obsolete on account of the great damage it causes to spruce-trees, and because the yield of resin from the spruce is insignificant, when compared with that from the maritime pine in France, and other pines in America. As the question has a certain importance for India, where profitable resin-tapping has been introduced, the account of this important industry given by Boppe in his *Technologie forestière* will be followed here with some additional information gained by the translator during his visit to the Forest of La Teste, near Arcachon, in 1894.—TR.]

SECTION I.—GENERAL ACCOUNT.

Crude resin is a viscous substance flowing from incisions in the bark of certain conifers (also from some broad-leaved trees * in tropical countries) which penetrate slightly into the wood, the operation being known as **resin-tapping**.

Among European species, the maritime or cluster pine (*Pinus Pinaster*, Soland.) may be tapped most advantageously for resin; this pine yields resin most abundantly near the sea-coast between Bayonne and the mouth of Charente, chiefly among the sand-dunes and *landes* (waste, sandy tracts) of Gascony. In other parts of France, where the maritime pine grows either naturally or artificially, resin-tapping is not sufficiently remunerative to be practised.

Although other conifers also yield resin, they do not furnish it in sufficient quantities for resin-tapping in their case to become a regular industry. In France, at any rate, their wood is too valuable to be exposed to the damage which the operation causes. However, as the silver-fir, spruce, larch, black pine and Aleppo-pine are sometimes tapped, it is useful to know how this is done. The Scotch, mountain and Cembran pines are not tapped.

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* Vide Fernandez, Utilization of Forests, p. 176.

The principal world-supply [*] of oleo-resin comes from the swamp or long-leaf pine (*Pinus palustris*), also from the loblolly pine (*P. Tæda*) and the pitch-pine (*P. australis*) of the North American States, North and South Carolina, Georgia and Alabama. Dr. Mohr states that 2,000,000 acres of these pines were being worked for resin in 1890, and that about 500,000 acres of new forest were taken up annually. In five or six years after these forests have been invaded, they present a picture of ruin and desolation painful to behold, the seedlings and poles being burned and all hope for the restoration of the forests excluded.

In India, resin-tapping has been introduced by Government agency in certain forests of *Pinus longifolia* in Jaunsár in the N.W. Provinces, and is practised on a careful plan based on that employed in Gascony. Resin may also be obtained in India from *Pinus excelsa* and *P. Khasya.*

SECTION II.—SUPPLY OF RESIN FROM THE MARITIME PINE IN THE LANDES OF GASCONY.

1. *Mode of Tapping.*

The maritime pine contains very large and numerous resin-ducts, and the flow of resin being much more active in the sapwood than the heartwood, superficial cuts into the former, which pass through these canals, cause the resin to flow into receptacles placed to receive it.

Towards the end of February or the beginning of March, in order to prevent pieces of the coarse external bark from mingling with the resin, the rough bark or rhytidome of the maritime pine is trimmed off as a preparatory measure, so that only a few inner cortical layers are left outside the sapwood; they then present a smooth reddish surface. Only portions of the trunk which are to be tapped during the ensuing season are thus prepared.

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[*] Extract from Report of Chief of the Forestry Division, U. S., Washington, 1892.

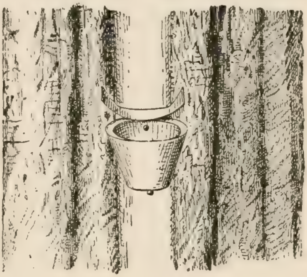
From the 1st to the 10th of March (according to the weather), the resin-tapper makes an incision with a special implement in the trunk of suitable trees. This is in the shape of a groove (*carre*) near the base of the tree and where the bark has already been trimmed, about 10 centimeters wide, 3 centimeters high, and 1 centimeter deep (4 inches by 1 inch by ⅜ inch). From this groove the resin flows in viscous transparent drops, which thicken on contact with the air: part of the resin thus solidifies, becoming attached to the surface of the groove; the remainder, being more liquid, flows into a receptacle which has been placed on the ground to receive it. Rain-water, which may fill the pots, always remains above the resin, the specific gravity of which is slightly higher than that of water.

Once a week, and once every five days during the season when most resin flows, the groove is freshly cut by slicing off a thin shaving of the wood at its upper extremity. The groove thus becomes gradually longer, its breadth remaining constant or being gradually reduced. As the groove becomes older, the resin ceases to flow: in freshly cutting it, the resin-tapper slices the surface of the top of the groove for a length of 10 to 12 centimeters (4—4¾ inches), his chief skill being shown in removing only a very fine shaving of the sapwood, so that the operation may be resumed several times without cutting deeper than 1 centimeter. This operation is thus effected forty to forty-five times during a season, but ceases after the 15th of October. The groove is thus cut in successive years up to a height of 3 or 4 meters (9¾—13 feet).

Formerly, the resin which ran from a groove was collected in a hole dug in the sand at the foot of the tapped tree. This method, which is now nearly everywhere abandoned, had many disadvantages. The sand in which the hole was dug absorbed much resin; besides this, when the groove became elongated, the resin had to traverse its whole length before reaching the ground. In flowing over the groove, therefore, the resin lost much volatile matter, and became hard; while needles, pieces of bark and particles of sand were blown on to it by the wind, and water or other impurities mingled with it.

In order to prevent the consequent waste of resin, Hugues, in 1860, devised a method for catching the resin immediately below the points of exudation by means of a little zinc collar which was fixed across the groove, and for collecting it in a glazed, conically-shaped pot, 14 centimeters wide at the top, 8 centimeters at the base (5½ and 3 inches) and 14 centimeters deep. Then, after cutting a groove, the collar is fixed below it, and the pot placed on the sand under the collar and gradually raised with the cut, as explained below. Every spring the whole apparatus is raised above the sterile portion of the groove, where the former year's tapping had stopped (Fig. 280).

Fig. 280.*



In order to fix the collar, an incision is made with a sharp, curved, steel implement, and the collar fixed in the incision. The pot is supported between the collar and a nail driven into the tree below the pot. The pots are also bored with a hole near their rim, so that they can be suspended if necessary, and this hole also allows any rain-water which is in the pot to drain away. Frequently evaporation of the turpentine is prevented by covering the pot with a thin piece of pine-wood. This improved system has increased the yield of resin by from 3 to 4½%, and also yields a much purer resin than before, selling at 10 francs a cask more than that collected in the sand.

Only the more liquid parts of the resin reach the pot, the rest solidifies on the way and remains attached to the groove. The upper part of this solid crust is easily removed by hand; it is thus collected by the resin-tapper, and is termed *galipot*. The resin in contact with the wood is much harder, and can be removed only by a scraping implement. This substance, mixed with chips of wood, is termed *barras*. When collected according to Hugues' method, hardly any *galipot* is produced, the residue being chiefly *barras*.

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* This, and all plates used in this chapter (except fig. 292) are taken from Boppe's *Technologie forestière*.

After the pot has become sufficiently filled with crude resin, the collector empties it into a kind of basket (*escouarte*), holding about 20 liters (4½ gal.) and made of rough cork, with wooden hoops, an osier handle and a round piece of wood for its base; at the same time he scrapes off the *barras*, which falls on to a cloth spread below the tree to receive it. The resin is then conveyed to reservoirs (*barcous*), formed of half-casks let into the ground alongside the forest roads, with removable, sloping wooden covers, which keep out the rain and impurities. The *barras* is either mixed with the crude resin in the *barcous*, or packed separately in palm-leaf baskets, imported for the purpose from Algiers or Egypt. From the reservoirs the resin is ladled out into casks, and carried to the factories in carts with very broad wheels, on account of the sandy nature of the roads. It is, however, proposed to improve transport of both resin and timber in the Forest of La Teste, by constructing a tramway to Arcachon, about 12 miles distant.

2. *Implements used.*

Various implements are used for cutting grooves, removing the crust of resin from the trees and conveying the produce to the factories.

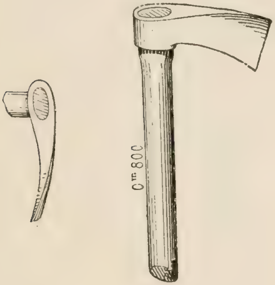
An ordinary axe is used for trimming the bark before the grooves are cut.

A curved axe (*abschot*), with a short handle (fig. 281), is used for cutting and freshening the surface of the groove. The blade should be sharp as that of a razor, so that the resin-ducts may be cleanly cut. Its irregular shape renders it an instrument difficult to construct and use; it can be used skilfully only after long practice, and experience in India shows that better work can be done there with an ordinary adze.

The scraper (*pelle*) (fig. 282) is made of iron, topped with steel; it is fixed to the end of a wooden handle a yard long. It is used for scraping the lower portion of the grooves, and under the old method, for digging holes in the sand and removing the resin from them.

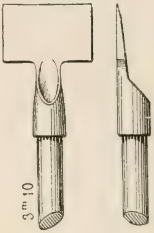
Another scraper (*barrasquite*) (fig. 283) has a curved, sharp blade with a handle 1½ meters (4 feet 10 inches) long. It is used for removing bark which cannot be reached by the axe and also for collecting the *barras* from the same places.

Fig. 281.



Abschot.

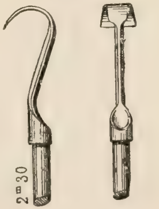
Fig. 282.



Pelle.

Another implement, termed *rasclet* (fig. 284), has a handle 1·80 meters (5 feet 10 inches) long; it has also a step, and is sometimes used to raise the height of the grooves when above the reach of the workman's *abschot*. The workman, however, frequently stands on the step of the *rasclet* and uses his curved axe.

Fig. 283.

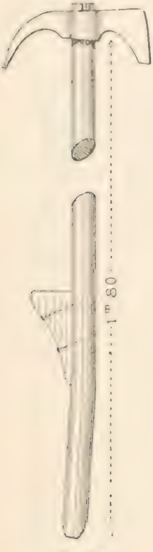


Barrasquite.

Fig. 285 shows another scraper (*pousse*), with a handle 2 meters 40 centimeters (7 feet 9 inches) long, and used, like the *barrasquite*, for the higher portions of the groove. The *palot* (fig. 286) resembles the *pousse*, but its handle is only 90 centimeters (1 yard) long; it replaces the *pelle*, when the Hugues method is adopted, and may also be employed as a dibble for sowing acorns or pine seeds.

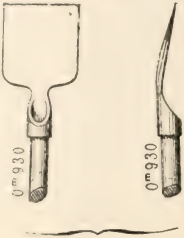
The resin-tapper also uses a kind of ladder (fig. 288) made of a small pine, into which steps are cut 30 centimeters (1 foot) apart. Each step is strengthened by a nail to prevent breakage. Considerable practice is required for a man to remain perched on this ladder whilst using the *abschot* with both hands.

Fig. 284.



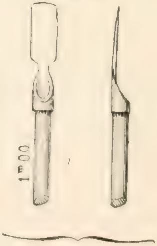
Raselet

Fig. 285.



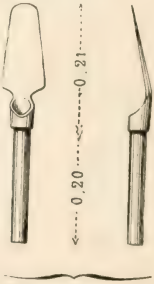
Pousse.

Fig. 286.



Palot.

Fig. 287.



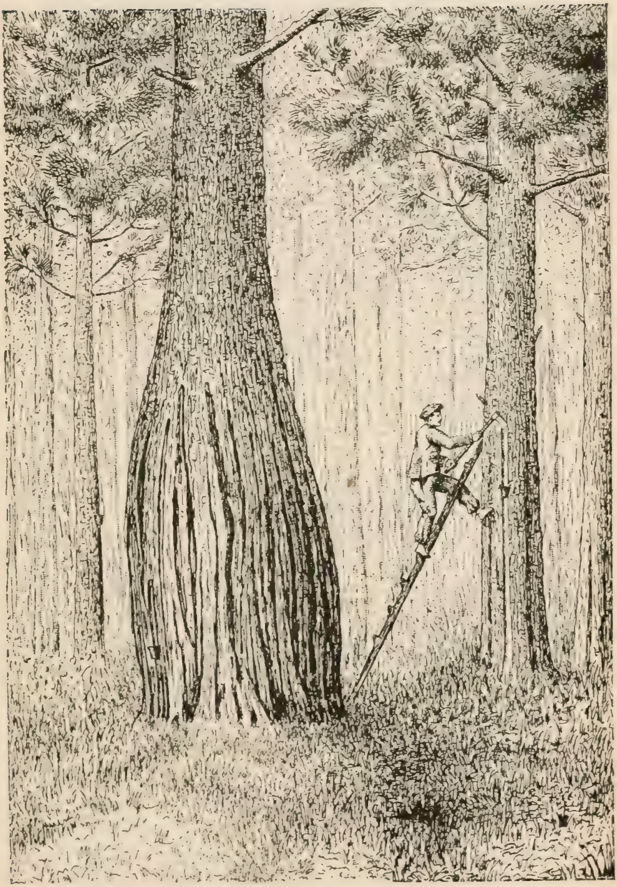
Espatule.

The spatula (fig. 287) is used for scraping off the resin which adheres to the pots or the *escouarte*.

The workmen make their own ladders and *escouarte*, and buy the other implements at the following prices :—

The axe, or *abschot*, 1 franc 50 centimes the kilogram (say 6*d*. a pound), or 6 or 7 francs each ; the *barrasquite*, 2 francs ; the *pousse*, 2 francs 50 centimes ; the *palot*, 1 franc 50 centimes ; the *pelle*, 2 francs.

FIG. 288.



Forest of La Teste.

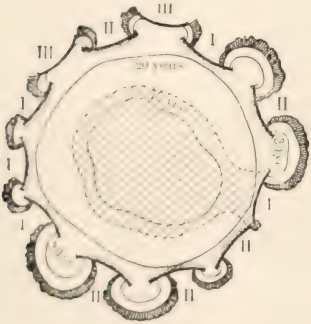
3. *Method of Cutting the Grooves.*

Commencing at the ground-level, the grooves ascend the stem as follows:—

End of—	M.	C.	Feet	Inches
First year	0	55	1	9
Second ,,	1	30	4	2
Third ,,	2	05	6	8
Fourth ,,	2	80	9	1
Fifth ,,	3	80	12	4
Thus in the first year the length of the cut is	0	55	1	9
Second year	0	75	2	5
Third ,,	0	75	2	5
Fourth ,,	0	75	2	5
Fifth ,,	1	00	3	3

The width of the groove is 9 centimeters (3 inches) for the first four years, and 8 centimeters (2½ inches) in the last year. Its depth must never exceed 1 centimeter ($\frac{3}{8}$ inch) when measured below a string stretched across the groove from the base of the bark.

Fig. 289.



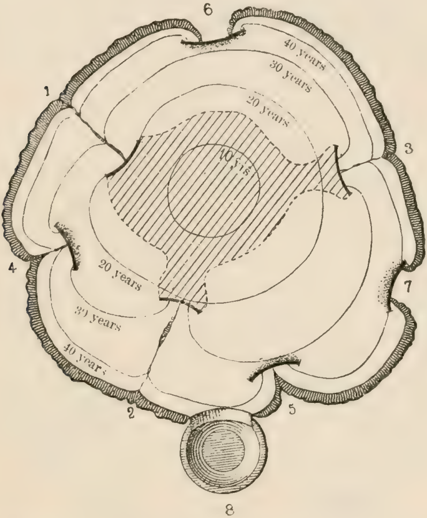
Roman figures refer to successive years' tappings.

The number of grooves cut at the same time in a tree vary according as the tree is **tapped without killing it**, or **tapped to death.**

Pines which are intended to be removed in thinnings and those which are considered mature are **tapped to death.** Such pines should remain standing for only a few years, and the greatest possible amount of resin should therefore be extracted from them. With this object, two, three, four, five and sometimes six grooves, according to its size, are cut in the same tree (fig. 289).

Pines are tapped **without being killed** when they are intended to remain for some time standing in a wood. They must be so tapped that their existence is not compromised, nor their vigour seriously diminished. It is therefore best, in this case, to make only one groove in a tree at a time. When, after five years, this groove is 3 meters 80 centimeters (about $12\frac{1}{3}$ feet) high, it is left untapped for several years, and then another groove commenced at 15 or 20 centimeters (5 to 6 inches) distant from the former, or on the other side of the tree exactly opposite to it. Thus, in time, grooves are made all round a tree, and fresh ones are then made between them. By this procedure, resin is extracted whilst the pines are kept alive for a long period (figs. 289, 290).*

Fig. 290.



Cross-section of a pine which has been repeatedly tapped "alive."

1. Groove cut when 19 years old.
2. ,, 22 ,,
3. ,, 27 ,,
4. ,, 31 ,,
5. Groove cut when 34 years old.
6. ,, 38 ,,
7. ,, 42 ,,
8. ,, 46 ,,

The last groove still in use.

---

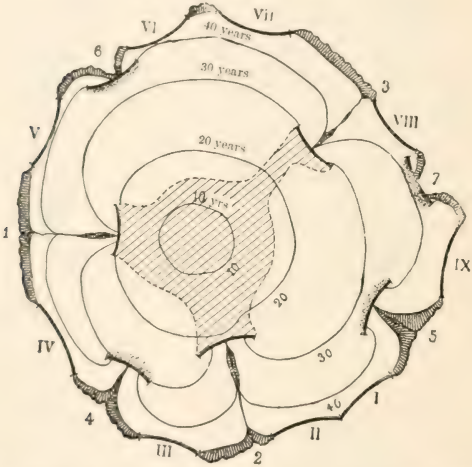
* In fig. 288 an old pine is shewn with a swollen base, and more than 50 grooves, it is probably at least 200 years old.

When, owing to a tree being exceptionally vigorous, or to bad treatment, two grooves are made at the same time, which is generally the case in private forests, they should be worked simultaneously at different heights.

4. *Treatment of Forests where Resin-tapping is Practised.*[*]

One of the best examples of a maritime pine forest in which resin-tapping is practised is the State Forest of La Teste, in latitude 45°, near Arcachon, bordering on the Bay of Biscay. It is situated on a sandy soil, with layers of iron-pan, termed *alios*. The rainfall is 32 inches and the mean temperature 56° F. With the exception, along the coast, of 1,580 acres of protection-forest which is very scrubby owing to the violence of the westerly winds and serves to protect the better portion of the forest from wind and shifting sand,

FIG. 291.



Cross-section of a pine first tapped "alive," and then tapped to death.

Grooves 1 to 7 made from age of 21 every 4 years to 45. Grooves I. to IX. made at the age of 51 years and have killed the tree.

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[*] This account is the result of a visit made by the translator to the forest of La Teste, in 1894, with Mr. Hearle, when M. Grandjean, the local forest-officer, kindly afforded full information regarding the management of the forest.

the remaining area (4,500 acres) is worked chiefly for resin. It is divided into 12 compartments, averaging 375 acres each, which are regenerated successively when from 55 to 60 years old, there being then from 80 to 100 trees per acre which are all tapped to death in the course of five years. The trees in a compartment 55 years old are for this purpose sold standing and must be felled within the five years, being meanwhile made to yield all their available resin. The undergrowth of pine seedlings, tree-heather (*Erica arborea*), arbutus, gorse, &c., is then cleared away, and the area sown naturally by seed which blows on it from adjoining areas, artificial sowing being effected, if necessary, to complete the regeneration.

Thinnings are commenced when the saplings are about five years old, maritime pine requiring more exposure to light than almost any species, especially if it is to yield resin as well as timber. These thinnings are repeated every five years, the trees being about 10 feet apart when 20 years old ; the material is not saleable in the Forest of Teste till it is 30 years old, being often given away gratis for fuel, or left to rot on the area, which it does rapidly. In older thinnings, trees over 1 meter 10 centimeters (3½ feet) in girth which are to be removed are tapped to death in five years, whilst the other trees over this girth are tapped alive, as already described. Trees of less girth are not tapped.

A workman and his wife * can fill 60 casks of crude resin (each containing 50 gallons) from 5,000 to 6,000 grooves, representing double the number of trees ; half the value of the resin collected (about 900 francs = £36) is paid him in return for his labour. One groove yields 2½ quarts in a year.

The estimated † outturn per acre of the fellings sold in 1894 was :—

	Age.	No. of trees tapped		Timber.	Fuel.	Resin.
	Years.	Alive	To death.	C. feet.	C. feet.	Gallons.
Final felling............	56–60	—	94	1,925	1,090	430
Last thinning	51–55	63	11	148	172	210

The timber is mainly cut into railway-sleepers and pit-props, which latter are chiefly exported to England.

---

* M. Grandjean has kindly supplied the following figures : (*a*) A groove on the average, according to the size of the tree, yields 1 kilo. 880 gr. (1 liter weighing about 1 kilo.) ; (*b*) A man can look after about 5,000 grooves in a season and collect 40 casks of 235 liters each.

† From account by N. Hearle, Indian Forester, July, 1895.

The French forest officials do not consider that 60 years is a long enough rotation to get the full benefit from the forest, especially in timber, and it is proposed to lengthen it to 75 years, with 15 compartments.

Private forests of maritime pine near Arcachon are chiefly managed for the yield of resin, and are consequently tapped younger and more severely than the State forests.

Boppe estimates that in a private maritime pine forest 45 years old each tree will yield 6½ to 10 pounds of crude resin per annum. The yield per acre varies greatly, according to the nature of the soil and the management ; 250 to 450 pounds per acre per annum are given as the extremes. The value of the cask of resin containing 235 kilograms (625 pounds) was 40 to 45 francs in 1885, but only 30 to 35 francs in 1894.

One of the reasons for the variation in price is that the spring-crop of resin is much lighter-coloured and freer from impurities than the autumn-crop, in which *barras* is added by the workman to the extent of 50 kilograms per cask.

The chief dangers in the forests of maritime pine are fires and invasions of shifting sand, the protective measures against which are described in Vols. II. and IV. of this manual.*

SECTION III.—TAPPING OTHER SPECIES FOR RESIN.

1. *Silver-Fir.*

Most of the crude resin in the silver-fir is contained in its bark, where a few drops of resin accumulate in little projecting blisters. It is collected by pressing these blisters with the sharp nozzle of a small tin vessel. This practice, which yields little and is being gradually abandoned, produces Strasburg resin.

2. *Spruce.*†

The spruce is tapped for resin by cutting long narrow grooves (3 to 6 centimeters broad and 1 to 1·5 meter long) through the bark of the trees down to the cambium-zone. As a rule, two grooves are thus cut on opposite sides of a tree, and when the supply of resin from them falls off, two more are opened between them (fig. 292). The crude resin pours over these grooves from the large radial resin-ducts and gradually covers them with a hard crust of resin. About a year after tapping, in the second summer, the workman removes this crust with a special iron implement, scraping it into a conical basket, made of spruce-bark, placed below the groove ; he afterwards empties the basket into a larger one, in which the resin is well pressed down.

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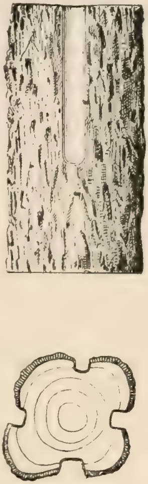
* An account of the products prepared from crude resin is given in Part iii., p. 770 of the present book.

† [This account is taken from Gayer.—TR.]

Fig. 292.



The callus which forms over the wound is cut about every four years to expedite the exudation of resin.

The process of resin-tapping causes decay in spruce trees, and by depriving the wood[*] of its resin reduces the quality of both timber and firewood. If, however, the usage be restricted to the last 10 years before the trees are felled no damage is apparently caused, except the reduction in size of the logs, due to the grooves cut in the stem.

The annual yield of resin from spruce trees in Thuringia 80 to 100 years old, when tapped during the last 10 years before they are felled, is 30 pounds of *galipot* and 43 pounds of crude resin per acre.

3. *Larch.*

Most commercial larch-resin comes from Austria, where two methods for its extraction are employed, as reported by Marchand.[†]

(a) **The Styrian Method.**—A hole, 2½ centimeters (1 inch) in diameter and 80 to 120 centimeters (2½ to 4 feet) long, is bored with an augur into the trunk of a tree as near the ground as possible, sloping upwards and passing across the axis of the tree. Crude resin exudes through this hole into a pot placed at its entrance, from which it is guided to the pot by a piece of spruce bark. Impurities are kept out by covering the pot with a leafy branch of spruce or a piece of bark (fig. 293).

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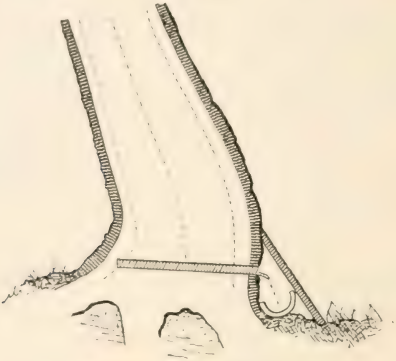
[*] The wood of the black and maritime pines, on the contrary, becomes more resinous when tapped.

[†] Mission forestière en Autriche, Arbois-Jarel, 1869.

Resin-tapping exhausts the larch, so that the resin is collected for a season only at a time, the hole being then stopped with a piece of wood which is removed after a rest of from two to six years, when the flow of resin recommences. By means of this precaution the tree may be tapped for 30 years, or more.

FIG. 293.



Styrian method of tapping larch.

(b) **Tyrolese Method.**—In this case (fig. 294) the hole in the larch tree is somewhat larger than the preceding one (3 centimeters) and is bored either horizontally or at an angle towards the axis of the tree, being then closed by a plug. The resin which accumulates in this hole is removed in autumn by means of a specially made spoon.

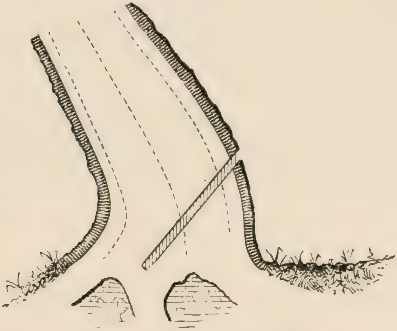
The process is only carried on at intervals, as in the preceding case; but, though it yields more resin at first, it weakens the tree more than the Styrian method and cannot be applied for more than 15 to 20 years.

Tapping the larch for resin yields very little profit to the owner of the trees—viz., about ½*d*. per tree annually. This is as nothing when compared with the damage caused to the wood; only trees 150 to 200 years old can be thus tapped.

4. *Black Pine.*

The black pine (*Pinus Laricio, austriaca*) is tapped in the Wienerwald by removing the bark from the base of the tree over about one-third (Gayer says two-thirds) of its circumference to a height of 40 centimeters (15 inches). A V-shaped niche, which serves as a reservoir for the resin, is then cut into the base of the tree, below this **blaze.** The blaze is trimmed several times in a season by cutting into the sapwood, and in succeeding years it is heightened annually by 40 centimeters, small pieces of wood being inserted in cuts made in the blaze, so that the resin may not form too thick a crust, but may fall into the niche. The crude resin is removed from the niche once a fortnight, and the crust and dry resin in autumn. Thus, at the end of 10 years, the blaze will be 4 meters (13 feet) high.

FIG. 294.



Tyrolese method of tapping larch.

These broad blazes are never occluded by new wood; the stem, however, becomes saturated with resin and does not decay. There is a considerable loss of timber, owing to the grooving.

The black pine yields from 2½ to 4½ kilos (5½ to 10 pounds) of crude resin per tree annually; 50 pounds of the crude resin yield 7 to 10 pounds of oil of turpentine, and about 30 pounds of colophany.

[E. McA. Moir, in charge of the resin-tapping of *Pinus longifolia*, in Jansar, states that in 1894–5, 6,318 trees were tapped and yielded 509 cwt. of crude resin (9 lbs. a tree). Each tree 6 feet in girth and over is tapped for three consecutive years and thus yields 11 to 15 lbs., the yield after the 3rd year's tapping being usually very small. 533 cwt. 64 lbs. of crude resin was distilled in the same year, and yielded 222 cwt. 16 lbs. of colophany and 621 gallons of turpentine. It is more profitable to sell the crude resin than to distil it; it is mixed with lac and used for making bracelets at Delhi.

In India, besides resin, various kinds of gums are collected for sale from numerous species of forest trees, also caoutchouc from *Ficus elastica*, gutta percha from species of *Dichopsis*, and from some of these products fairly large revenues are obtained. Since 1872, the Indian Forest Department has formed an extensive plantation of *Ficus elastica* in Assam, as it was found that the wholesale tapping of this valuable tree (which is only disseminated in the forests) would render it extinct.*—Tr.]

* Vide Fernandez, Forest Utilization.

CHAPTER IX.

LESS IMPORTANT MINOR PRODUCE.

The most important items of minor produce have been dealt with in the preceding chapters, but there are various other items which are more or less useful. Most of these are leased by area, either of the whole forest or for certain parts of it; permission is given to collect others gratis. Not unfrequently, however, it should first be decided whether their utilization will be injurious to the game in the forest, for permission given to persons to wander all over a forest in search of petty products may often give rise to irregularities. The following items of produce will be referred to :—

Grass-seeds.
Herbage for various Industrial Purposes.
Wood-wool.
Vanillin.
Mosses.
Knoppern Galls.
Truffles.
Edible Fruits.
Lime Bast, &c.

1. *Grass-seeds.*[*]

The frequently abundant growth of grass on clear-cuttings, forest-roads and other places has been already described, nearly all the species of grass occurring which are found in pastures. As meadow-grasses are cut for hay when in full blossom, meadows do not afford grass-seed; but in forests, grasses may be allowed to ripen their fruit and thus afford a useful agricultural product. The collection of grass-seeds is at present in many forests a matter of importance, employs many people and yields a fair revenue.

The species which, as good meadow-grasses, are chiefly in demand for seed may be classified as **gregarious, light-demanding** or shade-bearing grasses, and are included in the following list:—

---

[*] G. Rothe, *Sameln der Grassamen in den Waldungen*, Stuttgart, 1875.

Gregarious Grasses.

Fiorin-grass	*Agrostis alba*, L.: var. *stolonifera*, L.
,,	*Agrostis alba*, L.: var. *vulgaris*, With.
Bent-grass	*Agrostis canina*, L.
Meadow foxtail	*Alopecurus pratensis*, L.
Upright brome	*Bromus erectus*, Huds.
Meadow fescue	*Festuca elatior*, L.: var. *arundinacea*, Schreb.
,,	*Festuca elatior*, L.: var. *pratensis*, Huds.
,,	*Festuca rubra*, L.
Yorkshire fog	*Holcus lanatus*, L.
Perennial rye-grass	*Lolium perenne*, L.
Italian rye-grass*	,, ,, : var. *italicum*, A. Br.
Meadow poa	*Poa pratensis*, L.
Timothy-grass	*Phleum pratense*, L.
	&c., &c.

Light-demanding Grasses.

Grey aira	*Aira canescens*, L.
Yellow oat-grass	*Avena flavescens*, L.
Perennial oat-grass	*Avena pratensis*, L.
,, ,,	,, ,, : var. *pubescens*, Huds.
Common quake-grass	*Briza media*, L.
Field brome	*Bromus arvensis*, L.: var. *mollis*, L.
Crested dog's-tail grass	*Cynosurus cristatus*, L.
	&c., &c.

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* A variety probably raised by cultivation from British grass-seed, but now much imported from the Continent. Bentham & Hooker.

Shade-bearing Grasses.

Vernal grass	*Anthoxanthum odoratum*, L.
Tufted aira	*Aira cæspitosa*, L.
Wavy aira	*Aira flexuosa*, L.
Tall brome	*Bromus giganteus*, L.
Sheep's fescue	*Festuca ovina*, L.
Reed fescue	*Festuca sylvatica*, Vill.
Soft holcus	*Holcus mollis*, L.
Spreading milium	*Milium effusum*, L.
Wood poa	*Poa nemoralis*, L.

&c., &c.

When the seed is ripe (which for most grasses is in the latter half of June or July, and for others, in August and September) the collectors walk in lines through extensive grassy areas, grasp a handful of spikelets, cut them off and place them in a bag slung in front, which is emptied from time to time on to a large cloth spread out on the nearest road. The spikelets are then put into sacks for removal and again spread out in sunny places to dry, threshed and sifted. The chief points are to collect only one species at a time and entirely avoid seed of bad species; in his own interest the forest-owner should pay attention to this.

The revenue from the collection of grass-seed is sometimes considerable. In the State forests of the Grand Duchy of Hesse the revenues thus obtained in 1873 and 1874 were respectively £634 and £494. This covered from one quarter to one-sixth of the cost of re-stocking the annual felling-areas. In 1878 50 acres of felling-area in the Forest of Stockstadt, near Aschaffenburg, were leased for this purpose in one year for £31. Forstmeister Urich, at Büdingen, sows *Poa nemoralis* in beech felling-areas and on clear-cut areas, in order to produce a crop of valuable grass-seed. The seed of *Milium effusum* (common in Britain) is used as **bird-seed.**

2. *Herbage used for Various Purposes.*

Among herbage used for industrial purposes, other than those already described, *Carex brizoides* chiefly deserves mention; it is used instead of horsehair for stuffing furniture, &c. This sedge is found in Germany on the damp, rich, loamy soil of somewhat open spruce forests, also in coppice and coppice-with-standards of ash, alder, aspen, &c., where it grows in tufts between the overshading coppice-shoots and thrives in places sheltered from late frosts. The longer and softer the leaves, the more valuable the product. The sedge is full-grown by the end of June, and may be plucked from then till October; it is partially dried by spreading it on sunny roads, and then brought in and plaited. It is extensively collected in the Baden Rhine valley, where 5 cwt. of the grass per acre form a fair crop. The yield may, however, under favourable conditions, amount to 9 or 10 cwt. per acre; 150 pounds of dry sedge yield 125 pounds of plaits, worth 4*s*. to 6*s*. per cwt.

In the Grand Duchy of Baden at least 2,000 tons of sedge (worth over £12,500) are collected annually. In 1872, the town of Friburg obtained £1,287 for sedge removed from its forests; and other towns, £712 and £840. In 1873, several communes in Baden obtained 30*s*. to 60*s*. per acre for the sedge. More recently the demand has somewhat lessened, owing to the substitution of *Crin d'Afrique* (filaments from a palm, *Chamærops humilis*) as stuffing for furniture.

A grass (*Agrostis cæspitosa*) growing in damp forests and usually mature in September, is also used as stuffing material.

[The chair-factories at High Wycombe besides horsehair use **Alva**, as stuffing material;[*] this product is the dried leaves of *Zostera marina* belonging to the Nat. Order *Naiadeæ* and termed grass-wrack by Hooker. It is abundant, at or below low-water mark around the British Isles, on sandy or muddy edges of the sea and is often thrown up in large quantities by the tide.—Tr.]

Rushes are chiefly used as packing material for bottles of superior wine and for the seats of chairs. **Share-grass** (*Equisetum*) is used for polishing furniture, and is largely exported from Germany to Greece, Turkey, and Hungary.

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[*] [Communicated by Mr. Glenister, High Wycombe, the plant being identified by Marshall-Ward.

Mr. Isaacs of Mark Lane, states that alva is imported by the ton, in pressed bales, from Holland, France, and Germany, at prices varying from £3 15*s*. to £9 per ton of 20 bales. It is mowed in the sea, as, if dragged out, it is not curly and springy and suitable for stuffing chairs, &c. Also used by florists.—Tr.]

3. *Preparations of Scotch Pine Needles.*

In many districts, especially in Silesia, green needles of freshly-felled Scotch pine are used for preparing a woolly material used instead of sheep's-wool, in stuffing matrasses, quilts, &c., and commercially known as wood-wool.

Green needles are boiled in water or a weak alkaline lye, or allowed to ferment and then macerated, and their fibres separated by repeated washings until a felt-like mass remains, retaining the fibres as far as possible unshortened. This is repeatedly saturated with water, macerated and washed until it has become very fine, and is then dried. The brownish or greenish wood-wool is then bleached, and becomes a more or less white and bright felt, and is ready for sale.

A hundredweight of the finest wood-wool* is worth 50*s.*, inferior kinds selling for 12*s.* a cwt. Boiling Scotch pine needles yields a product termed oil of pine needles. A perfume is also obtained from Scotch pine needles termed "essence of forest air or of silver-fir" (*Waldluft- oder Tannengeist*).

4. *Vanillin.*

Hartig, about 10 years ago, discovered a substance in the cambium of conifers belonging to the group of glucosides, and named by him **coniferin.** This substance has been further split up into fruit-sugar, and a second organic substance, which, in colour, scent, taste, and crystalline form resembles vanilla, and is named **vanillin.**

Vanillin is now being prepared on a large scale in Thüringia, and is largely used in confectionery. The trees are felled in May and June; the cambium-zone is shaved off, and the sap collected in vats and barrels.

5. *Mosses.*

Polytrichum commune, a moss often growing a foot high in wet places, is used for making brushes which are fashionable in France, the material chiefly coming from Germany. The moss is cut in the forest, tied in thin bundles and steeped like flax; it is rolled on ribbed planks, again heated to render it pliable, and is then ready for use for weavers'-brushes, scrubbing-brushes, carpet-brushes, &c. The roots of the common crowberry (*Empetrum nigrum*, L.) and of *Polytrichum commune* and *P. urnigerum* are also used for brushes, velvet brushes being made from the latter in Rhenish Prussia.

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* Vide Dankelmann's Zeitschrift, viii. 425.

At Aachen, in 1853, *Polytrichum* in the rough was sold at 9*s.* per cwt., and at Trier the prepared material at 12*s.* to 40*s.* per cwt. Tamarisk-moss (*Hypnum tamariscinum*) is largely used in the manufacture of artificial flowers, *Hypnum splendens* being less valuable. In Germany, 100,000 tons of this material are used annually, being valued at £3,000. Tamarisk-moss is chiefly found in beech forests, and the other moss among conifers; they are collected in summer, kept dry under cover, and during winter the separate fronds are cleaned, pressed between leaves of paper, sorted, dyed and packed.*

6. *Knoppern Galls.*

The oak forests of Hungary and Servia yield an important product in the galls produced on the cups of pedunculate acorns (termed, commercially, **knoppern galls**), which fall in September, are collected and carefully dried on shelves, and sold as a valuable tanning material. Although the price is at present very low, still, 20*s.* to 30*s.* a cwt. are obtained at the place of production.

Knoppern galls, as a rule, are only obtainable every 8 to 10 years; plenty of acorns, a warm summer, plenty of gall-flies and an open crop of oak trees, are essential conditions. In 1860 the production of Austria-Hungary was estimated at 7,000 to 12,000 tons. This yield has subsequently decreased, owing to the destruction of oak forests.

7. *Truffles.*

The truffle (*Tuber melanosporum*) is the most valuable of edible fungi; it is chiefly found in oak, elm and ash forests, a few centimeters underground, in damp, rich soils of the warmer parts of France and Germany. [It was formerly fairly common in oak forests in the south of England, and is still found in Sussex and Hampshire.—Tr.] Other species * of truffles, especially *T. æstivum* and *Choiromyces meandiformis*, are found from Hannover to the river Vistula. The importance of truffles may be gathered from the fact that 1,500 tons (worth £640,000) are exported annually from France; in the whole of Germany only about a ton (worth £35) is collected yearly.

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* Dankelmann's Zeitschrift, iv., p. 159.

In Perigord, land formerly stocked with vineyards is now planted with young oaks for the cultivation of truffles, which grow as a *mycorhiza* on the oak roots. This is said to pay three to five times as well as vineyards. Whole villages are engaged in this industry, which has now gone beyond the experimental stage. [When the high price is considered at which truffles are sold, there is every reason for endeavouring to grow them in the south of England and Ireland.—Tr.]

8. *Edible Fruits.*

Cranberries and bilberries are the edible fruits most frequently collected from forests. In many districts all the children are engaged during the season in collecting these berries, and a large trade driven in the produce; there are commercial houses in North Germany which deal with them to the extent of £5,000 and more yearly. The forests of the Fichtelgebirge, the Spessart, the Schwarzwald, &c., yield large quantities of these berries. When fully ripe, large wooden combs are used to strip off the berries into baskets. Only a small part of the produce is now used for brandy; it is chiefly made into wine, partly to convert white wine into red wine and partly as bilberry wine, which is sold at Frankfort-on-Maine and other places as a medicinal beverage; it is also sent in large quantities to the south of France to be mixed with grape-wine and sold as claret.†
Bilberries may be also eaten fresh, cooked or dried.

Several municipal forests in Germany sell annually from £25 to £50 worth of bilberries. In the forest-range of Ottenhöfen, in Baden, £250 worth were sold in 1855, and for the same value in the forest division of Schaidt, in the Palatinate, in 1882. It is well known what enormous quantities of strawberries, raspberries, alderberries, &c., are annually gathered. In the village of Frammersbach, in the Spessart, children yearly collect these berries to the value of £200.

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* Cf. R. Hesse, *Die Hypoganen Deutschlands*, Halle, 1891.

† E. Laxis, in Handelsblatt für Walderzeugnisse, 1894, No. 23.

Mistletoe-berries are here and there collected for making bird-lime. [Branches of mistletoe for Christmas form a yearly article of trade from Normandy to London, whole steamer-loads arriving from the Norman apple-orchards.—Tr.]

9. *Lime-bast.*

The inner bark, or bast, of the lime tree (termed Russian bast) is used for making ropes, string, shoes, dusters, for use by gardeners, packing material, mats, sacking, &c. Lime-bast is used for many purposes in Russia, and exports of different articles thus made from Welisch are valued annually at 30,000 to 40,000 roubles.

In Brandenburg and Galicia, thin roots of Scotch pines are used for cables, withes and basket-work.

10. *Other Items.*

Among the multifarious forest plants which are used industrially or medicinally may be mentioned:—Orchid bulbs, as salep; spores of *Equisetum clavatum*, for violet powder; roots of valerian and berberry (*Berberis vulgaris*) and flowers and fruits of a number of shrubs and herbs for medicine. Lime-blossom is habitually sold for tea in Hungary: about 5 cwt. annually.

The beetle Spanish-fly (*Lytta vesicatoria*) is also collected for sale in Hungary.

[The items of minor forest produce exported from the Indian Forests, such as medicinal drugs, dyes, paper material (Bhābar-grass —*Ischæmum angustifolium*—*Daphne papyracea*, bamboo, &c.), textile fibres, lac, wild silk, honey and wax, besides those already mentioned in former chapters of the present book, are far too numerous to be described here. Reference on the subject is invited to Watts' Dictionary of Indian Economic products, and Fernandez' Forest Utilization.—Tr.]

PART III.

AUXILIARY FOREST INDUSTRIES.

BESIDES the production of raw material from forests, there are several industries with the details of which a forester should be acquainted, as they either form part of his regular duties or are nearly related to them. They may therefore be termed **auxiliary forest industries.** With one exception they are all based on the conversion of raw forest material into commercial products, the exception being **peat,** which might therefore have been classed among minor forest produce.

In former times it was undoubtedly advantageous to the forest owner to conduct some of these industries under his own direct control. Private enterprise has, however, gradually intervened, and most foresters now prefer to confine their exertions to the production of raw material, since owing to the increasing specialisation of industry and the difficulties of dealing with labour, it is an acknowledged maxim, at least as regards State ownership of forests, that the State should not compete unnecessarily with private enterprise. There are some foresters,* however, who consider it necessary or advantageous to direct auxiliary forest industries, especially when the profit made by the middleman in converting raw material into saleable wares is thus secured by the forest owner, or when private enterprise fails to utilize the raw material to the best advantage; also in cases where it is necessary to lead private enterprise in the right direction, and thus, by producing goods of superior quality, obtain a better market for them. In the same way agriculture is not restricted any more than forestry to the production of raw material, but undertakes many industries which are properly of an auxiliary nature.

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* [This is especially the case in the Sihlwald, a forest belonging to the town of Zurich, where the wood is worked up in detail into all kinds of mercantile produce, besides being treated on the spot with antiseptic substances.—TR.]

Since, therefore, several auxiliary forest industries are often directly conducted by the forest owner, or by the State, the most important of these will be now described in the following order:—

I. ANTISEPTIC INJECTION OF WOOD.

II. USE OF MACHINES FOR CONVERTING WOOD.

III. CARBONISATION OF WOOD.

IV. DIGGING AND PREPARING PEAT.

V. HUSKING AND CLEANING CONIFEROUS SEEDS.

[VI. PREPARATION OF RESIN AND TURPENTINE.—TR.]

[A short account of the preparation of wood-pulp has been already given on p. 160, and of oil from beech-nuts on p. 569. In India distillation of sandal-wood oil and manufacture of kutch, lac and caoutchouc are simple industries which may be profitably undertaken by forest-owners, and in which the State can lead the way to improved processes, as explained by Fernandez in his "Utilization of Forests."—TR.]

CHAPTER I.*

ANTISEPTIC TREATMENT OF TIMBER.

1. *General Remarks.*

The constantly increasing demands on oakwood for railway sleepers during the latter part of the present century, and the greatly reduced supply of this durable material, have led to the adoption of methods for artificially increasing the durability of other timber. Much has therefore been done of late in this respect, woods which were formerly considered unsuitable being now employed for constructive purposes after injection with various antiseptic substances. The methods employed are not yet completely satisfactory, but highly beneficial results have been obtained which may lead to still greater improvement.

The preservation of timber is greatly in the interest of the forest owner, for were it possible to use beech and other broad-leaved woods, oak sapwood and inferior coniferous wood in the place of oak heartwood, much forest produce would thus be rendered more valuable.

[In India, among the hundreds of indigenous timbers which the forests produce, only a few such as teak, sal, deodar, sissu, will withstand the attacks of white ants, and consequently there are in the forests large supplies of timber which can be used only for inferior purposes or are practically unused. This is especially the case with the enormous supplies of pine, spruce and fir timber in the Himalayan forests. It is extraordinary that, although the question of injecting these timbers with antiseptic substances was brought to the notice of the Government of India by Sir D. Brandis, as early as 1877, nothing has been done in this respect. Although creosote may not be available for the purpose at a sufficiently low cost, chloride of zinc is extensively used in Germany and N. America for injecting timber. Even if the soft coniferous woods are not all suitable for railway-sleepers, yet the injection would protect them from white ants and other insects, and render them suitable for building purposes: thus an immense supply of cheap wood, which is now allowed to rot in the forests, would become available for the dense population of the north of India. This is the more necessary, as much Indian wood is too heavy for cheap transport, whereas these light woods can be easily floated down the rivers to places on the railways, where the injecting works might be established, and the timber converted into suitable assortments and transported further by rail.—Tr.]

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* Buresch, der Schutz des Holzes gegen Fäulniss. 2nd Ed. Dresden, 1880. Blythe, notes sur les différents traitements employés pour la conservation des bois. Paris, 1880.

[Boulton on antiseptic treatment of timber; Proceedings of the Institution of Civil Engineers, vol. 78. pt. iv. (1883-4), also S. B. Boulton on creosoting timber, 1885.—Tr.]

The different establishments where the injection of timber is effected are chiefly intended for the preservation of railway sleepers, but a commencement has been made in utilizing injected timber for other purposes, viz., for mining-props, shingles, house furniture, vine-stakes, telegraph-posts, wooden street-pavement, &c.

The subject of the present chapter is the artificial injection of timber with antiseptic solutions. The nature of the effects of these solutions on wood tissues is not yet fully understood. It is intended to fill the air-spaces in wood with substances which impede the decomposition of nutritive material which cannot be entirely removed from the tissues, so that the growth of fungi may not be nourished by them nor by the woody substance. [Insect-attacks are similarly prevented.—Tr.]

The action of injection is therefore two-fold, protecting timber from decay and from destruction by insects. Methods of injecting timber differ according to the nature of the substance injected, the method of injecting, and the natural suitability of the wood in question. It should also be noted that many injecting substances are soluble in water, and may therefore, sooner or later, be washed out of the wood and their efficacy thus lost, [whilst others act injuriously on iron bolts which may come into contact with the injected wood.—Tr.]

2. *Materials used for Injection.*

A number of substances have for a long time been known which render wood durable, such as resin, essential oils, camphor, tannic acid, acetic acid, heavy tar-oil (creosote); also several salts, as green, white and blue vitriol (sulphates of iron, zinc, and copper), chlorides of iron, zinc, mercury or magnesia, Glauber's salt (sodium sulphate), common salt, &c. Only a few of them are, however, applicable on a large scale and of these the following are at present in the front rank:—**sulphate of copper, chlorides of zinc or mercury, heavy tar-oils** (creosote) and **milk of lime.** There are also a few other substances the use of which is still only in the experimental stage.

Injection with **sulphate of copper** (blue vitriol) was first employed in France on a large scale by Boucherie, and has been extensively used for the last sixty years for building-timber, railway-sleepers and telegraph-poles. This method was at one time extensively used by railway companies in France, Austria, and Bavaria; this is no longer the case, though it is still here and there employed for telegraph-poles, stakes and other small pieces of timber exposed to decay. Wood injected with sulphate of copper is harder than wood in its natural condition, but is rendered more brittle and weaker by the process.

[The salt is also easily washed out of the wood and it reacts on all iron with which it may come in contact, so that iron-fastenings applied to wood so treated must be galvanised, or coated with zinc and the wood tarred at the points of contact.—Tr.]

Sir W. Burnett, in 1838, patented a process of injection by means of **chloride of zinc**, which is at present used in many German, Austrian and American railways. Chloride of zinc is one of the cheapest antiseptic substances and recent experience has proved that it is preferable to sulphate of copper.

[Chloride of zinc does not corrode iron but is said to be washed out by water; to prevent this the Wellhouse * process has been invented in America. Glue is added to the solution, which is forced into the timber, and subsequently a solution of tannin is pumped into the injecting chamber, at a pressure of 100lbs. to the square inch, forming with the glue a leathery substance which fills the pores of the wood and prevents the washing out of the zinc chloride.—Tr.]

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* Engineer, Sept. 11, 1891.

The use of **chloride of mercury** (corrosive sublimate) was patented in 1832 by the Englishman Kyan as a preservative for timber.

Kyanising was for some time extensively used in Britain, and is useful in dry situations but useless in sea-water; corrosive sublimate being a strong poison has also the drawback of injuring the workmen who are employed in handling it, it also corrodes iron and is somewhat **volatile at ordinary temperatures.**

Products from the distillation of coal or wood containing more or less heavy tar-oils, carbolic acid, tar, acetic acid, &c., are chiefly used in the form of heavy tar-oils from coal-tar, the process being introduced by Bethell, in 1838, and subsequently termed **creosoting,** though there is no true creosote in coal-tar. The coal-tar is obtained as a residual product of gas-works and is distilled by being subjected to the heat of a furnace, yielding certain oils lighter than water (naphthas), oils heavier than water, and pitch, which runs out from the bottom of the still and solidifies into a hard black substance. Formerly the heavy oils were used without further distillation for preserving timber, but Boulton considers that the tar acids (including carbolic acid) which they contain, are speedily washed out of injected timber and that the heavier portion of the oils which clogs up wood-pores is more valuable than carbolic acid as a preservative of timber. It is essential that wood should be air-dried before being creosoted, the method by which this is secured will be described further on. Wood-tar is less used than coal-tar, though it is undoubtedly superior to it for injecting timber, the main difficulty with coal-tar being its viscosity and the consequent difficulty of driving it deeply into wood. Boulton maintains that Newcastle coal produces heavier oils than other English or Scotch coal and that the lighter **country** or **Scotch oils** penetrate more deeply into timber but do not produce such a lasting effect as the heavier **London oil** from Newcastle coal. —Tr.]

Creosoting is chiefly employed in Britain and is now being increasingly used in France, Germany and other countries; although the method of injection now employed is capable of improvement, it is undoubtedly superior to injection by any metallic salts. Creosoted wood is hard, tough and black, much less absorptive of moisture than uncreosoted wood and does not form chemical combinations with metals. On the Emperor Ferdinand Railway, in Austria, a mixture of chloride of zinc and carbolic acid is being used with good results.

Blythe at Bordeaux injects wood with steam containing tar-oils.

[Boulton considers that no good can result from this, the light oils being too volatile to remain long in the timber; on the other hand, the injection of heavy oils in the form of vapour is prevented by their high boiling point ranging from 400° to 760° F., while timber is rendered brittle and unsafe for engineering purposes at a temperature of 250° F.—Tr.]

Stuart Monteith first used **milk of lime** to fill the pores of timber; this method has been reintroduced by Frank and is useful for preserving furniture and other woodwork under cover, but its utility is doubtful for wood in the open.

[An American, Haskin, has introduced a process termed **vulcanising**, by which green wood in trucks is passed through an iron cylinder $6\frac{1}{2}$ feet in diameter and 112 feet long, where it is subjected for a few hours to compressed air at temperatures of 300° to 500° F.; this converts the sap of the wood into neutral oils, resins, &c., which act as antiseptics. Haskin maintains that this high temperature does not weaken the wood.—Tr.]

3. *Methods of Injection.*

The method of injecting wood by the various substances already referred to is as influential on the result as the antiseptic substance itself. The most important methods are:—**hydrostatic injection, pneumatic injection, imbibition by immersing or boiling** the wood in solutions of the antiseptic substances.

(a) **Hydrostatic injection.**—At first the antiseptic liquids were absorbed by natural force of the foliage raising the sap, incisions being made with this object at the base of the stem of a standing tree. This method was abandoned owing to its impracticability [and the fact that the foliage exerts only an upward pressure equivalent to that of 10 or 12 feet of water.*—Tr.]. Boucherie discovered that a pressure of one or two atmospheres applied at the transverse section of a log is sufficient to expel the sap and replace it by another liquid.

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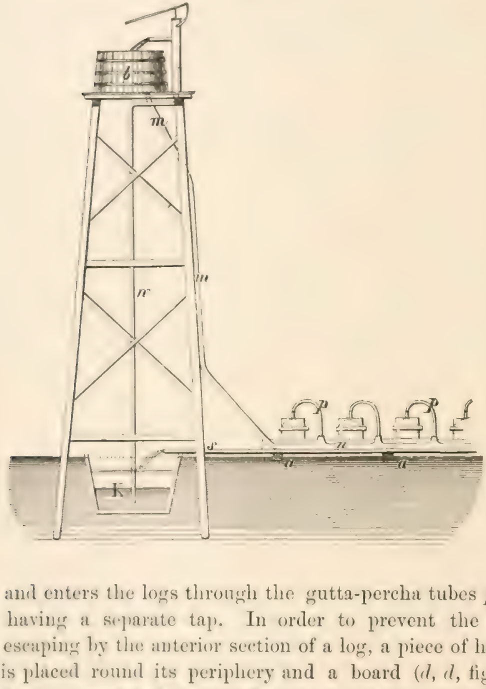
* Boppe op. cit., p. 93.

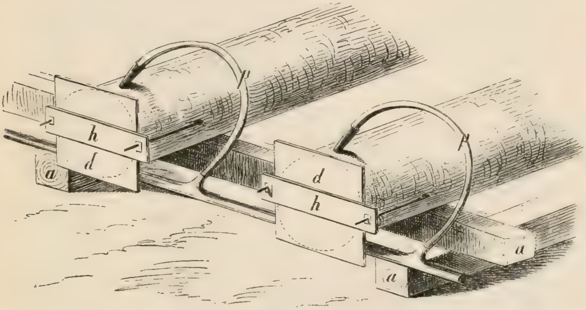
Stems or poles, with their bark intact, are placed nearly horizontally (fig. 295, *a*, *a*) on a timber framework; the liquid (1 part sulphate of copper to 100 parts of water) flows from a vat *b*, which is supported on a trestle 26 to 32 feet high, passing by the pipe *m* into the conducting tube *n* under the ends of the logs, and enters the logs through the gutta-percha tubes *p* each tube having a separate tap. In order to prevent the liquid from escaping by the anterior section of a log, a piece of hempen rope is placed round its periphery and a board (*d*, *d*, fig. 296) placed over a rope and pressed firmly against the log by a press *h* and two tension screws and nuts. The section of the log, the board *d* and the piece of rope placed in a ring between them, enclose a hollow space with which the gutta-percha tube communicates by means of an oblique augur hole bored in the log. The solution of sulphate of copper flowing from the

FIG. 295.



vat d, with a pressure due to its height above the ground, is therefore driven into the log and expels most of the sap, which issues from the smaller end of the log, at first pure but eventually mixed with the injecting solution. This waste liquid flows into a wooden trough s, and is then conducted to the tank K, which is provided with a filter to exclude impurities [and also a basket full of crystals of the injecting substance in order to maintain the strength of the solution.—Tr.] The liquid in K is then pumped back into the vat b by the pump w. Instead of forming the hollow space at the base of the log by means of a piece of rope, Oesau used a metallic vessel, like a round, shallow box, the sides of which are sharpened so that they can be driven into the base of the log with a few blows of a hammer, whilst there is an orifice in the base of the box into which the tube p is screwed.

Fig. 296.

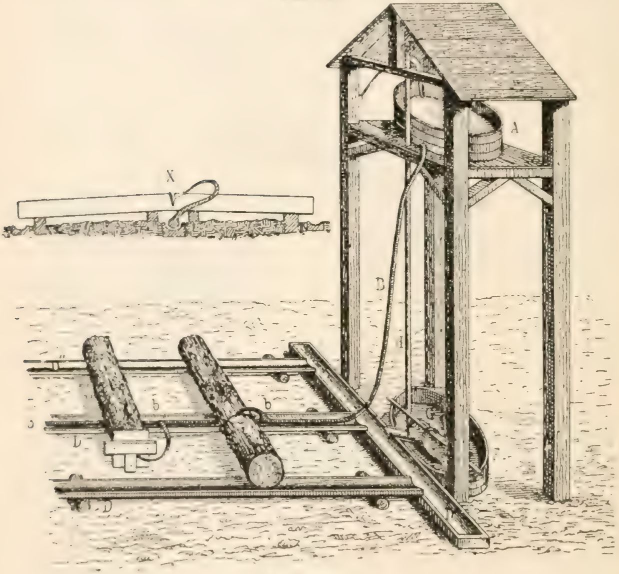


[Boppe states that long logs in France are injected by being sawn nearly across at their middle (fig. 297), so that a thickness of only 1½ to 2 inches of wood is left below, the log is then raised by levers and a piece of rope inserted in the opening. On removing the levers, the log returns to its former position, and the cut closes tightly on the rope; an augur-hole is then bored obliquely through the log into this hollow space, and the gutta-percha tube placed in it as before.—Tr.]

Wood to be thus injected should be freshly cut, and still full of sap. Stems are therefore topped, branches cut down to short snags, the bark left uninjured and the injecting process applied as soon as possible. If the base of a log has dried it should be again freshly cut before being injected. Logs kept in water for a long time preserve the faculty of being injected.

[The free ends of the logs are tested, either by their colour, or by a chemical test to ascertain when the injection is sufficient.—Tr.]

Fig. 297.



After Boppe.

In order to inject logs satisfactorily by Boucherie's process, a long time (up to 70 hours) and a large timber-yard are required. The injected logs are dried slowly and as thoroughly as possible, they are then barked and converted.

When freshly felled stems are injected the bark must be completely preserved, or the injecting liquid will escape. If, however, they have been kept for about three months, the preservation of the bark is not material, as the sapwood dries down for a few centimeters and becomes impermeable for liquids.

Another improved method based on that of Boucherie is that carried out by Pfister.* Instead of pressure due to a fall of about 30 feet, Pfister used a portable forcing-pump producing a pressure up to 20 atmospheres, he thus drove the injecting liquid through tubes into the wood, the tubing being so arranged that it can be lengthened at discretion or conducted at the same time to several logs. The advantages of this method are, that the injection is more rapidly effected than by Boucherie and in the forest immediately after the felling of the trees or poles, without any necessity for transporting them to the injecting works.

Pfister's apparatus will thoroughly inject a beech-butt 10 feet long in about half an hour, it being immaterial whether the bark is damaged or not. He also devised an improved method of enclosing the base of the logs. The apparatus, with several different sized closing pieces, costs £200 to £300.

(b) **Pneumatic injection.**—Antiseptic substances can be injected into wood more effectually by means of a forcing-pump than by the hydrostatic method, the process being then much more rapidly conducted: at present pneumatic injection is exclusively employed in Germany in the case of chloride of zinc, creosote, acetic acid, &c.

In this case the wood is first converted into beams, scantling, railway-sleepers, &c., and is then placed in large iron cylinders (*A*, *A*) containing the injecting liquid, which, at temperatures of 112°—194° F. (50°—90° C.) is pressed into the wood by powerful steam forcing-pumps.

The pieces of wood to be injected are packed as tightly as possible on the trucks (fig. 299), and the latter are then pushed along a tramway (*m*, *m*, fig. 298) into the cylinders *A*, *A*. When the cylinders are full, the rails leading to them are removed and the head *x* adjusted and firmly fixed so as to close the cylinder. The wood is then at first steamed at a temperature of 112½ C. (234½ F.) for one hour; the steam is conducted from the boiler *M* through the steam-pipe *a*. When the steaming process is

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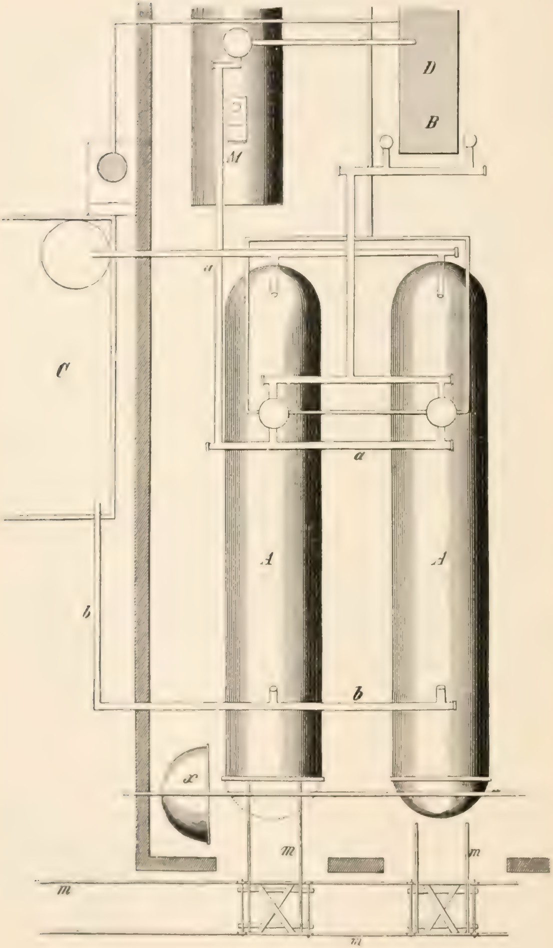
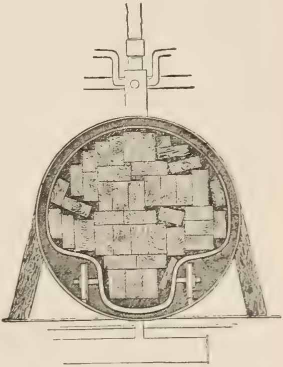
* Dimitz und Böhmerle, Centralblatt des gesammten Forstwesens, Vienna, 1889.

FIG. 298.


D
B
M
C
a
a
A
A
b
b
x
m
m
m
m

concluded, the air is sucked out of the wood by means of the air-pump *B* and the injecting liquid (30—50 fold diluted chloride of zinc, the latter containing 25% of zinc) is admitted through the pipe *b b* into the cylinders, the air-pump still working for some time. When the cylinder is full, the forcing-pump *D* presses the liquid into the wood. In order to effect this a pressure of about 6 atmospheres is applied for ¾—1¼ hours. The injecting liquid is then drawn back into the reservoir, and the truck removed with its contents. The two cylinders are used alternately.

FIG. 299.



Front of an injecting cylinder with a truck laden with wood.

Quite recently it has become the practice to omit the steaming entirely and to dry the wood, especially in creosoting with tar-oil, &c. It is, however, desirable, in order to render wood durable, that all the nutritive material in the sap should be withdrawn, which is not the case when the wood is dried. The drying is effected in a drying-chamber, heated to 175°—250° F. The wood is then placed in the injecting cylinders, out of which the air is drawn, and the tar-oil admitted at a temperature of 113°—140° F. (45°—60° C.), and pressed into the wood in the same way as when chloride of zinc is used.

[Boulton* says that the presence of water in timber at the time of creosoting is most prejudicial to successful injection, and that railway-sleepers and other timber should be stacked and dried for several months before injection. This precaution can easily be secured in the case of railway-sleepers or telegraph-poles, but when timber is sawn from logs kept in timber-ponds in the docks, it is difficult to afford a proper time for stacking and drying it before creosoting.

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* S. B. Boulton, "An improvement in the process of Creosoting Timber."

Owing, however, to the injury done to timber by drying it artificially at temperatures up to 250° F., the action of stoves in closed chambers, or of superheated steam, is very prejudicial; he therefore considers 230° F. as the limit of safety for heating timber intended for engineering purposes. Boulton has therefore patented a process depending on the different boiling points of water (212° F.) and of heavy tar-oils (350° F. to 700° F.); the creosote is admitted at a temperature slightly over 212° F. and the action of the air-pump continued, so that any water in the logs is converted into steam and drawn off by the air-pump through a condensing worm in a dome on the top of the injecting cylinder. The creosote is still liquid at 212° F. and replaces the water in the log, which is not then subject to any excessive heat and consequently its tissues are uninjured. Boulton also maintains that in the case of railway-sleepers to be used in India and other hot countries, this injecting at a temperature of 212° F. fills all cracks in the wood with creosote; as in India therefore the sleepers will not be subjected to such a heat in the ballast, they will not crack any further there, which is not the case with sleepers injected at a heat less than that they may experience in Indian ballast.—Tr.]

When heavy tar-oil is used for injecting purposes, the wood is coloured dark black; the hard, pitchy components of the tar form a crust almost as hard as stone on the surface and fill all the crevices of the wood. [In England about 50 gallons of heavy tar-oil are used per load of 50 cubic feet, the oil weighing 11 lbs. per gallon.—Tr.]

F. Löwenfeld has designed a portable apparatus for injecting wood, which is based on the principle of first steaming the wood and then injecting it by forcing-pumps in chambers deprived of air. There are six of these chambers, which can be successively connected with the steam-generator and in which the process of injecting is carried on continuously, the sixth chamber being removed and charged with wood, the first chamber steamed, and so on.

In Blythe's system (according to Gayer) the wood is first artificially dried and then placed in boilers, where it is subjected to a high pressure of steam containing heavy oil of creosote in suspension. The wood is subjected to injection from 6 to 20 hours, and is completely injected, assuming a dark colour like that of several tropical woods. The softened wood is then rolled and pressed till it is reduced in thickness by 10% or even 40% The effect of the injection is thus increased by compressing the wood, and a very superior kind of furniture-wood is thus produced (Exner). It is preferable to use freshly felled wood, and Exner states that beechwood thus injected and compressed gains up to 19% in strength.

(c) **Steeping converted wood in antiseptic liquids.** — This method is chiefly employed for *Kyanising* stakes and small pieces of wood. Large wooden troughs like cooling-troughs are partly filled with a solution* of corrosive sublimate in water, the pieces of wood are placed in them, weighted to make them sink and kept from 8 to 10 days immersed. Stakes are merely placed in petroleum casks filled with blue vitriol solution and other antiseptic liquids.

[Boulton says that small pieces of wood, hop-poles, fencing-slabs, stakes, &c., may be placed in an open trough with heavy tar-oil, which is heated by a fire under the trough, care being taken not to raise the temperature of the creosote above 230° F.—Tr.]

Other methods by immersion give inferior results. Formerly the wood was frequently boiled in antiseptic liquids, steam being introduced into the vessel in which the wood was immersed until the liquid in it boiled. Blue vitriol, borax solution, &c., were thus injected, but the liquid must be kept at the boiling point for 10 or 12 hours.

H. Liebau, in Magdeburg, has recently attempted to introduce the liquid from the interior of the pieces of wood instead of externally, in order to protect the heartwood from decay. This can be used only for stakes, piles, &c., the axis of which is bored through after they have been driven into the ground and tar-oil, pitch, &c., poured into the cavity. Nothing can yet be said as to the efficacy of this method.

[Boppe states † that in France mining pit-props are immersed for about 24 hours in solutions of 1½lbs. per gallon (150 gr. to 1 liter) of sulphate of iron, or in wood-tar heated to a temperature of 278° F.

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* According to Tredgold's Carpentry by Hurst, 1871, 1lb. of corrosive sublimate to 10 to 15 gals. of water, 1½lbs. of the sublimate in the strongest solution being enough for a load or 50 cubic feet of wood.—Tr.]

† Technologie Forestière, p. 97.

(140 C.), in order to render them more durable. It is found that if the immersion is continued for a longer period, the wood becomes brittle, and that chloride of zinc, blue vitriol or creosote poisons the wood and renders it dangerous to the miners.—Tr.]

4. *Suitability of different Wood for Injection.*

The question as to the comparative ease or difficulty with which a piece of wood can be injected and whether the injection is thorough, or merely superficial, cannot as yet be satisfactorily answered. As a rule, a thorough injection is rare, in most cases the antiseptic liquid merely injects the sapwood and younger woody zones; in the case of railway-sleepers which are injected pneumatically, it also passes into the two ends of the sleepers, whilst the heartwood in the centre is often only partially injected. There are, however, many modifications in the above condition of injected wood, according to the species of wood, its soundness or unsoundness, special anatomical structure and amount of contained resin, which differs greatly in individual cases.

According to species, woods without heartwood, or with imperfect heartwood, are much more easily injected than those with heartwood.

It has been proved by experience, that the beech is the wood most easily injected and that hornbeam, aspen, birch and alder come next, then spruce and silver-fir. As regards heart-wooded trees, although the sapwood may be readily injected, it is an exception when the heartwood can be injected at all and then only partially. Different woods also absorb antiseptic liquids in different degrees; thus on the Kaiser Ferdinand Railway, 50 cubic feet each of oakwood and Scotch pinewood absorbed respectively 240 lbs. and 570 lbs. of antiseptic substance. In fact the more porous a wood the more easily it is injected.

[Boulton states that up to 600lbs. of heavy tar-oil may be absorbed by a load of timber.—Tr.]

The degree of soundness of the wood is also influential in this respect, as only sound wood-fibres are capable of injection. Young wood being generally sounder than old wood is more absorbent than the latter.

The more resinous a wood the less easily it is injected and much resin in wood may entirely prevent injection, as for instance in Scotch pinewood; it has not yet been ascertained whether the different injecting processes affect matters in this respect.

Beechwood with reddish false heartwood (from trees over 100 years old) is quite unsuitable for injection. It is not yet known whether variations in the specific gravity of the same wood affect matters in this respect; this question should be decided experimentally.

5. *Results of Injection.*

Reference has been already made (p. 120) to the results ot injecting railway-sleepers; it was stated that the locality, nature of the soil and wear and tear on a railway must be considered in judging the durability of injected sleepers. The method of injection, the anatomical structure of the wood and whether the injected wood is used immediately after injection or is first kept some time in store, also affect its durability.

As regards the methods of injection, the following results are given by German Railways:—

Nature of antiseptic substance.	Method of injecting.	Life of sleeper in years.			
		Oak.	Scotch pine.	Beech.	Spruce.
Chloride of zinc......	Steam-pressure	19—25	22·8	13—15	—
,,	Immersion	—	—	—	6·6
Creosote	Steam-pressure	19·5	—	18	—
Sulphate of copper...	Hydrostatic pressure	—	16	—	—
,,	Immersion	—	14	—	9·6

Löwenfeld found the following percentages of antiseptic substances in sleepers after being used for 13 years:—

	Chloride of zinc.	Tar-oil.
Oak...............................	45	31
Larch	51	41
Beech	71	42
Scotch pine........................	28	21
Spruce, Silver-fir	83	55

In comparing the durability of injected and uninjected railway-sleepers it may be stated that on the average:—

Beech	durability trebled.
Scotch pine	,, doubled.
Oak	,, ,,
Spruce	,, increased 50%

According to Buresch, beech railway-sleepers injected with chloride of zinc last only 8 or 9 years, but their life is reckoned at 18 years on the Köln-Minden railway, whilst a thoroughly injected beech-sleeper costs only half the price of an oak-sleeper.

It is clearly proved by experience on many railway lines and by numerous carefully conducted experiments that injected beech railway-sleepers are quite durable enough to be extensively used, yet only 1% of the sleepers used on German lines and 3% in Austria-Hungary are of beech. This non-use of beech is therefore unjustifiable, and the different State Forest Departments should therefore endeavour to supply large quantities of beech sleepers from sound young trees, whilst the railways should use them only after thorough injection by steaming and when they are air-dry.

It appears that when chloride of zinc is used, the injected sleepers are more durable if laid down a few months after injection and not fresh from the injecting works.

The cost of injection varies according to the method employed. Buresch has given figures for a number of German lines on p. 82 of his valuable book already referred to, being as follows per cubic foot:—

	d.
Chloride of zinc (steam-pressure)	2·04
Sulphate of copper (Boucherie)	2·28
Kyanising	3·72
Kreosoting	4·92

In Germany the cost of injection per railway-sleeper is given as follows by Nepomacky:—

	Oak. *d.*	Scotch pine. *d.*
Sulphate of copper (Boucherie)	4·1	5·2
Chloride of zinc (steam pressure)	8·3	10·3
Corrosive sublimate	9·6	11·6
Creosoting	14·8	24·2

In considering therefore the good results of the process of injecting wood with chloride of zinc under steam pressure, it is the process most highly to be recommended for Germany. The question whether wood injected with metallic salts loses strength and becomes brittle, requires further investigation.

[As already stated, the objection to the use of metallic salts for injecting wood is chiefly that they are liable to be washed out by rain, although they usually penetrate more deeply into the wood than heavy tar-oil. There is a further objection to the use of sulphate of copper or chloride of mercury, that they react injuriously on iron, but this objection does not hold for chloride of zinc, which appears to answer satisfactorily in a comparatively dry country, such as parts of Germany. Mr. W. H. Preece* gives some interesting facts as regards the durability of injected telegraph-posts in England. In 1844, the line of telegraph between London and Southampton was constructed with posts of best Memel timber Burnettised with chloride of zinc ; and in 1857, the following per-centages of decayed posts were observed :—

On sand	40 per cent.
On clay	33 „ „
On chalk	28 „ „

In 1871, all the posts had to be removed. Unprepared telegraph-poles last 7 years, Boucherised poles 15 years. In 1848, 318 poles on a line of 20 miles from Fareham to Portsmouth were creosoted by Mr. Bethell, and in 1883, every pole but two was sound. On the South Western Railway along the line from Yeovil to Exeter, in 1861, poles were put up alternately, as follows : first, an uninjected pole ; then, a Boucherised pole ; then, a creosoted pole, and so on for 40 miles. In 1870, all the uninjected poles were rotten, and 30 per cent of the Boucherised poles, while not one creosoted pole had gone bad.

Creosoted red-pine sleepers used on English railways appear to last from 8 to 12 years, but much depends on the amount of traffic.

Bouisson of the Western Railway of France states† that on the line from Rouen to Dieppe, creosoted beech sleepers were laid in 1859, and in 1878 not one of them showed any signs of decay, though beechwood unprepared becomes completely decayed in 2 or 3 years. Grantham† also stated that on the Great Western Railway in England, creosoted Baltic sleepers last 8 to 10 years and uncreosoted 5 years, and that kyanised sleepers last 6 to 7 years.—Tr.]

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* Proceedings of Institution of Civil Engineers, vol. 78, p. 174.

† Minutes of Proc. of Inst. of Civ. Eng., op. cit. p. 659.

CHAPTER II.

SAW-MILLS.*

SECTION I.—GENERAL ACCOUNT.

THE transportability of the wood produced by a forest considerably influences the revenue of the latter. Timber in the round cannot, as a rule, bear transport to a distance and timber-prices would in general be very low, were it not possible to convert heavy logs into planks and scantling and thus facilitate their transport to a distance from the forest. This conversion is chiefly effected by saw-mills situated either in or near the forests, the existence of which enables many forests to be worked at a profit and affords a market for their timber.

[It is stated that saw-mills were run by water-power in Germany as early as 1322. An attempt to establish a mill in England in 1663 was abandoned owing to the opposition of the sawyers, and one erected at Limehouse, in 1768, was destroyed by a mob. North America is the home of saw-mills, one having been erected in Maine in 1634.†—TR.]

The question whether saw-mills should be managed by forest owners, or left to independent private industry, has, in the German State forests, with few exceptions, been decided in favour of the latter alternative. The State should not, however, hesitate to favour and support saw-mills, as its interest lies clearly in that direction. As, moreover, saw-mills are sometimes controlled by forest owners, especially private owners of large forests, and it is desirable that foresters should possess some knowledge of their mode of construction and management, a general account of them is included in this book.

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* Saw-mills, by M. B. Bale, London, Crosby Lockwood & Co., 1888.

† From Encyc. Brit., 1886, Saw-mills, by Hotchkiss.

Not very long ago, the simply constructed saw-mill, hundreds of which are still found in coniferous forests, was the only means employed for converting logs into scantling. The marvellous improvements in machinery and in the use of water- and steam-power, and improved communications, have recently not only elaborated and multiplied saw-mills, but have also led to the construction and use of numerous other wood-working machines.

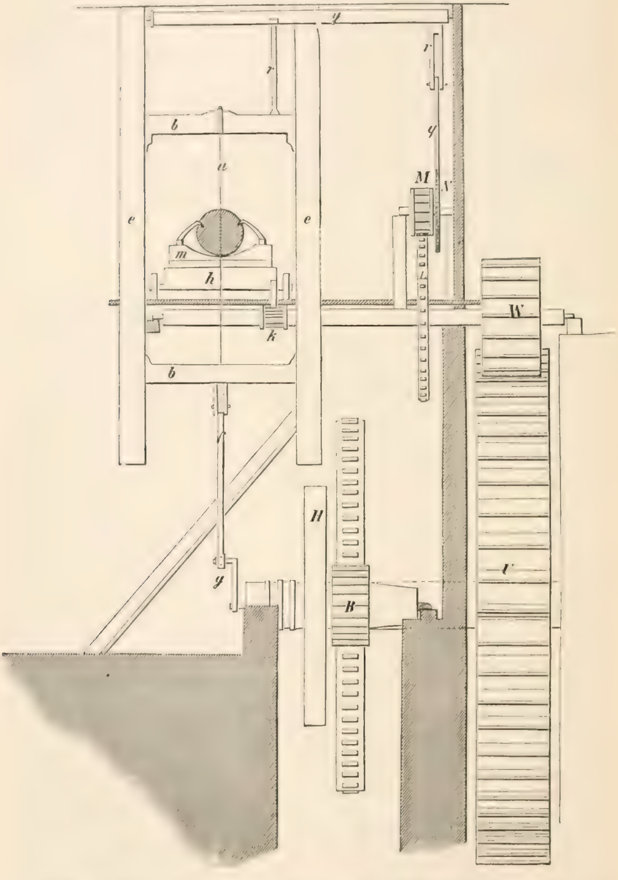
It should also be noted that the better kinds of simple saw-mills are by no means obsolete, but deserve full consideration on the part of forest owners as long as they produce marketable material at cheaper rates than large saw-mill establishments in towns.

SECTION II.—FOREST SAW-MILLS.

1. *Description.*

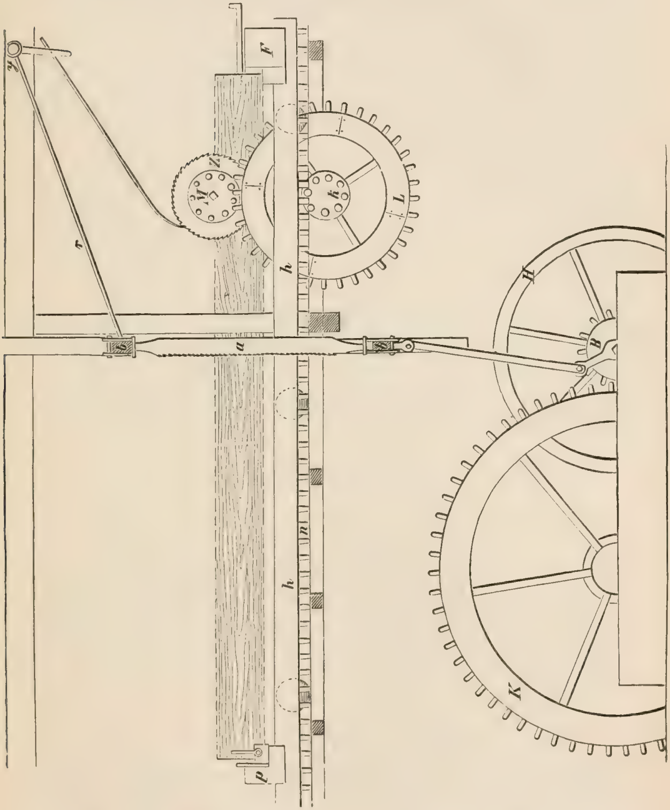
The ordinary forest saw-mill is characterized by its position in a forest, its usually simple mode of construction, by being driven by water-power and having as a rule only one blade to a saw. It consists of three parts, the **frame** which moves up and down with the saw, the **travelling** or **butt carriage** supporting the logs which are to be sawn and the **mechanism** for setting both the above in motion. The saw-blade *a* (figs. 300, 301), is nearly vertical and fixed in the frame *bb*, moving up and down with it between the wooden slides *ee*; below the frame is a pitman *f* which is attached to a crank *g*. Every revolution of the wheel *B* drives the saw up and down by means of *g*. The cut is effected by the downward stroke of the saw, the steep edges of the teeth being pointed downwards. During the upward stroke, the butt to be cut must be pushed forward against the saw. With this object, the butt is placed on the carriage *h*, which consists of a long, somewhat narrow, strong platform. The head-blocks *P* and *F* are dovetailed into the carriage at each of its extremities and serve to hold the butt in position. The carriage is pushed forward by means of a rack *n*, which is driven by the pinion *k* of the cog-wheel *L* and the latter by the cog-wheel *M*, on the axle of which another cog-wheel *N* is fixed and driven by the ratchet *q*; *q* is connected by a hinge with one of the levers *rr* attached to a cylinder *y*, which is moved through part of a rotation and back again, by the motion of the other lever *r* attached to the upper part *b* of the saw-frame.

FIG. 300.


q
r
r
b
q
a
M
N
e
e
m
h
L
W
k
b
f
H
V
g
B

Thus, every upward movement of the saw-frame forces *q* against the wheel *N*, which is thus set slightly in motion and communicates the motion through the cog-wheels *M*, *L*, *k*, and thus pushes forward the butt-carriage and the butt against the saw. At the downward motion of the saw-frame, the ratchet *q*

FIG. 301.



is drawn backwards, catching a cog in *N* when the saw is at its greatest height and again forcing *N* round at the next down stroke of the saw. *U* is the water-wheel which drives the saw, the small water-wheel *W* being used to drive back the butt-carriage, when the butt has been sawn through. *H* is an iron fly-wheel which regulates the motion of the machinery.

As soon as the butt has been sawn through its entire length, the butt-carriage is pushed back as far as it will go, and the butt adjusted for a second cut and so on, till it has been completely sawn into planks.

Recently, many forest saw-mills have been improved* in various ways; some of them, however, are still sadly wanting in this respect. The improvements are mainly directed to improving the outturn of saw-mills, both in quantity and quality. The most important of these are the material of which the machinery is constructed; the mode of suspending the saw-blade; its form and the nature of the teeth (their thickness, shape and set); the movement of the carriage and the mode of fastening the butt on to it; the rapidity of the saw, &c. Besides these points there are several others, so that evidently, there are at present many different kinds of saw-mills.

An efficient saw-mill should utilize all the available **water-power**, should yield a sufficiently **large outturn** of planks, the latter being **clean-cut**; there should also be **little waste of wood** and **economical working** should be ensured.

2. *Material Used.*

If all the parts of a saw-mill are constructed of wood, they must be very massive and hence require considerable motive power; much friction is thus caused. The more, therefore, iron is used instead of wood, the less these inconveniences are felt; on this account, the saw-frame and the guides between which it slides as well as the wheels and driving mechanism are made of iron in all new saw-mills.

3. *Mode of suspension of the Saw.*

As a rule, there is considerable resistance offered to the down passage of the saw-blade by the butt. If the saw is suspended vertically, the first tooth of the saw which strikes the butt would do all the work in sawing, the other teeth passing uselessly through the cut made by it. In order then to divide the work equally among the teeth and afford room for the butt to come forward during the up-stroke of the saw, the crank gives a forward motion to the blade in its downward cutting stroke and a retreating motion as it rises from the cut. The distance by which the topmost overhangs the lowest tooth is termed the **slope** of the saw. On this depends the cleanness of the cut.

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* See W. Kankelwitz, Der Betrieb der Sägemühlen, Berlin bei Gürtner, 1862; J. D. Dominikus, Das illustrirte Handbuch für Sägemüller und Handsager, Remscheid-Vieringhausen, 1889–90.

4. *Kind of Teeth Used.*

The most usual mode of construction of the teeth is that shown in fig. 302, the cutting side of the teeth being somewhat out of the horizontal line. Fig. 303 shows the old German pattern of teeth which is still sometimes employed. The area of the teeth is usually in a ratio 1 : 2 to that of the spaces between them, but in the case of saws used throughout the year for sawing coniferous wood, this ratio may be as low as 1 : 3.

Fig. 302.

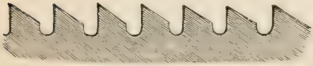
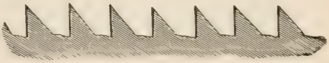


Fig. 303.



5. *Thickness of Blade.*

It is highly important for saws to have a proper thickness of blade. Too thick a blade wastes much wood and motive power, for the latter must be greater the more sawdust is produced and the broader the cut. When, however, a stronger motive power is used the tension of the blade must be greater, this involves a heavier frame and increased strength in all the other parts of the mill. All this causes increased resistance and friction. Too thin a blade, on the contrary, is not sufficiently stiff, easily becomes heated, its tension becomes slack and it then cuts in a wavy manner ; it may also fail to cut through hard knots or annual zones in the wood.

Saws for hardwoods and for resinous, knotty wood of many conifers should be thicker than those used for soft, clean-grained coniferous wood free from knots. For blades of moderate length 1¾ to 2½ mm. may be considered the best thickness for saws. Saw-blades are now made even thinner than this, while formerly blades 5½ to 7 mm. thick were used. Thin blades give a cleaner cut than thick ones. A good blade should also thin off towards its back. From average annual results recorded in the Harz mountains, it appears that with old thick saw-blades the sawdust amounted to 10 or 11 % of the whole butt sawn, whilst with thin blades it is only 2½ %. There are, however, in the large coniferous forests, where the price of wood is low, many saw-mills where the loss of wood still exceeds 12 %.

6. *Set of the Saw.*

The extent of the set of the saws also considerably influences the loss of wood. Setting facilitates sawing, but only at the expense of the outturn, both in quantity and quality. Old-fashioned saws working in wood of good quality usually have a set of 0·75 to 1·00 of the thickness of the blade, causing the werf to be often 7 mm. and more. Attempts have recently been made either to dispense altogether with the set or reduce it as much as possible.

7. *Length of Blade.*

The length of the saw depends on the thickness of the butts and on the play of the saw (*i.e.* double the length of the crank *g*, fig. 300). The shorter the blade the greater its possible tension and the cleaner it cuts. The shortest length possible is double the thickness of the largest butt which is to be sawn. In a good saw-mill this minimum should be only slightly exceeded; evidently the play of the saw must correspond with this.

8. *Mode of Fixing Butts on the Carriage.*

The butts must be firmly fixed to the carriage, so that it remains rigid while being sawn. Numerous contrivances have been invented with this object in view.

9. *Rate of Motion of the Carriage.*

The rate at which the butt-carriage moves towards the saw must correspond with the rate of the saw and the depth of the cut. The butt must not be too forward for the action of the teeth; in order, therefore, not to overtask the teeth, the butt must advance less than the slope of the saw and size of the teeth apparently permit. In most old saw-mills the depth of the cut is between 6 and 12 mm.; in new ones between 30 and 36 mm. Instead of the old arrangement of the rack and pinion feed, rollers are used, by means of which the workman has a far better control over the rate of progression of the carriage.

10. *Rate of Sawing.*

The rate of sawing depends on—the relation of the amount of motive power available to the mechanism in use; the degree of resistance offered by the wood and of friction by the saw during the sawing; also the amount of play of the saw, for the greater this is for a given motive power the less rapid is the rate of sawing. In old saws the play of the saw was often 0·60 to 0·80 meters, with a moderate water-power and moderately-sized butts 70—120 strokes were given in a minute. When a return was made to short blades and the play was reduced there was an increase in the number of strokes per minute. Superior saws of new construction have a play of 0·30—0·50 m., and give on the average 200 strokes in a minute. It should also be noted that the more rapid the sawing the greater space should be left between the teeth of the saw.

11. *Economical Working.*

The value of a saw-mill depends also on economical construction and labour. It is evident that simple forest saw-mills driven by water-power, in which only a small capital is invested and where owing to their situation in the forest transport-charges are minimised, can work cheaply and compete with large saw-mills which have more difficulty in securing cheap raw material. As regards the quality of the planking, however, which depends on the best mechanism, as a rule, the large mills are superior, owing to their smooth cut.

SECTION III.—STEAM SAW-MILLS.*

1. *Frame-saws.*

Although most of the saw-mills which will be now described are driven by steam, the use of water-power is not excluded; it must then be strong and steady so as to be suitable for powerful turbines. Whilst forest saw-mills usually work with only one saw, or at most two saws, steam saw-mills are supplied with a number of saws and other wood-working machines, so that they can turn-out wood completely ready for use in buildings, &c. They differ chiefly from forest saw-mills by their enormous outturn and its better quality.

Besides differing from forest saw-mills in these points and in their motive power, steam saw-mills are also constructed differently; being completely formed of iron they are more compact, stronger, possess greater stability and work more evenly; friction is reduced to a minimum and they are much more powerful. This greater power is specially utilised in steam saw-mills by there being several saws, up to 10, in the same frame, all of which work at once; a butt is thus sawn into planks in one operation. These are termed **multiple saws.** As regards the power required to drive multiple saws, it is estimated that 3 horse-power is required for the empty frame alone, one horse-power for the first four blades and for every other blade half a horse-power. These saws are constructed on the same principle as ordinary saws, but mechanical improvements are introduced to increase their efficiency and reduce the motive power required to drive them.

Figs. 304 and 305 represent one of the numerous kinds of multiple saws from the catalogue of Kirchner & Co. of Leipzig. The frame, which is generally driven from below (*A*), runs very smoothly in simple bearings (*a a*) and may support 10 to 20 blades at suitable distances. The blades are usually fixed in the frame by wedges. The butt to be sawn is supported on carriages (*m m*), one on either side of the saw and both running on a light tramway, on which it is firmly secured by iron dogs (*n n*). Two pairs of removable grooved iron rollers (*z z*) above and below the butt press it forwards against the saw. As soon as the butt has been sawn through it is removed by butt-carriages in front of the saw, another butt is then brought up

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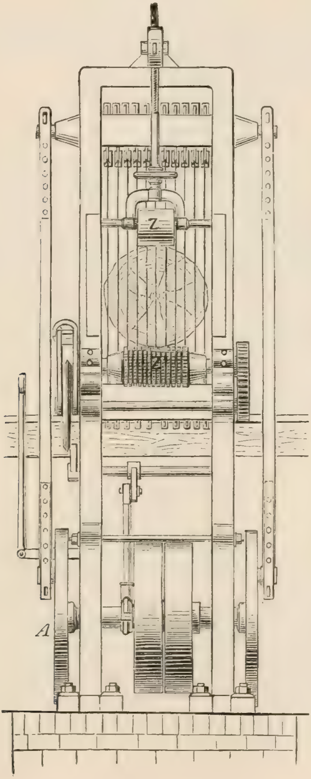
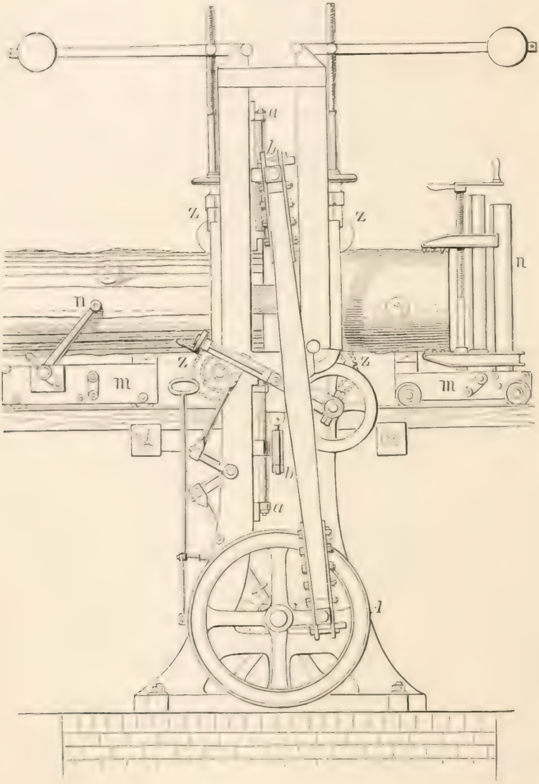
* An excellent account is given of modern American saw-mills by Hotchkiss, in Encyc. Brit., 1886, vol. xxi. Also see Worssam & Co.'s catalogue (King's Road, Chelsea).

FIG. 304.



from behind into contact with the saw. No time is lost, as in forest saw-mills, in reversing the butt-carriage while butts and

FIG. 305.



logs of any length may be sawn. Fig. 306 shows the same saw in perspective.

In order to save time in sharpening the saws (which must generally be done every 6 or 7 hours) the frame with the saws in it can be easily removed and another with freshly-sharpened saws substituted.

The best steam saws have a play of 30 to 50 centimeters (12—20 inches), giving 200 to 300 cuts a minute. For sawing coniferous woods they have very thin blades with scarcely any set; they turn out planking, whenever a large quantity of raw material is available, at rates scarcely dearer than ordinary forest saws. It should also be noted that saw-mill engines are often driven by burning sawdust and refuse wood instead of coal, this being rendered possible by the use of special furnaces.

Fig. 306.

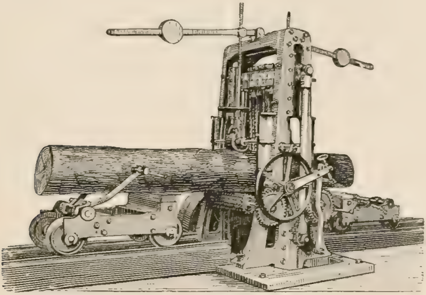
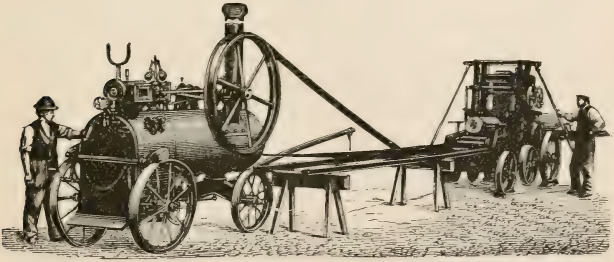


Fig. 307.



Besides fixed saw-mills, portable frame-saws, termed in America pony-saws, are now employed. Fig. 307 shows their mode of construction, they are on wheels and are driven by a belt from a locomobile; they are valuable in forestry from the fact that it is more natural to transport saws to the forest, than wood in bulk from the forest to the saw-mills.

California is at present ahead of all other countries in saw-mills, not only in constructive ingenuity, but also in the use of mechanism to replace manual labour in working the mills. As the question there is one of entirely clearing the forests of wood, for which purpose tramways are expressly constructed and penetrate every year deeper into the forests, it is evidently business-like to set up pony-saws in the midst of the forest; nowhere therefore are various kinds of pony-saws more the order of the day than in California. They generally work with circular saws.

2. *Circular Saws.*

Circular saws consist of a circular thin steel blade furnished at its rim with a continuous row of teeth and capable of rapid rotation round a horizontal axis. These saws are vertical, and only about $\frac{2}{5}$ of their area is available for work.

Circular saws require a comparatively low motive power; their dimensions vary considerably from 8 in. to 4 feet (0·20—1·20m.) diameter, whilst the thickness of the blade varies from 1 to 3·5 mm. A moderate-sized circular saw moves, at its circumference, at the rate of 50—65 feet (15—20m.) a second, for hardwood and 65—100 feet (15—30m.) for softwood.

The commonest uses of circular saws are as follows:—

i. Large circular saws for removing side-pieces from beams, thus replacing much tedious work with the adze. Although this can also be done by frame-saws, yet the circular saw is often preferred, as it works the more quickly of the two. By means of mechanism, the log resting on rollers moves automatically towards the saw.

ii. Large saws for cutting butts into planking; these are generally used after the butts have been sawn in half by frame-saws. Circular saws are much more commonly used for this purpose in America than in Europe.

[Where driven by engines of from 25 to 100 horse-power, the circular saw-mill will turn out 20,000 to 60,000 feet a day in addition to running double edgers and trimming saws, trimming off the rough edges and bad ends of the lumber.*—Tr.]

iii. Double-edging circular saws for edging planks and boards consist of two saws on the same axis, the distance between them being capable of adjustment. They feed by rollers.

iv. Saws for laths resemble the above, but there are 3 to 5 blades on the same axis, which cut up planks into laths or other scantling.

v. Ordinary circular saws, used for sawing planks into thin boards, such as those used for cigar-boxes, packing-cases, staves, &c. The wood may either be pushed by hand along a bench to the saw, or automatic feed may be adopted.

vi. Another form of circular saw is used for shortening logs, removing bad ends of planks, refuse wood, &c. These saws may be either fixed or portable.†

3. *Band-Saws.*

A band-saw is a long thin flexible steel ribbon uniting to form a belt and bearing teeth on one side. It passes above and below over two large pulleys, the lower pulley driving the saw, while the upper one is driven by it. Thus, like the circular saw, the band-saw cuts continually, and also either vertically or horizontally.

Band-saws require 25 to 40% less motive power than circular saws, the friction caused is also less and very little waste of wood is caused, saving 20% compared with other saws. They yield smooth and fine scantling.

Band-saws were first used in small work, either with a fixed or moveable table, and especially for cutting along curved lines. More recently they have been used for sawing large butts (fig. 308) and are now ousting frame-saws for this and other purposes, especially in America, where the band-saw is considered the saw of the future and can turn out 40,000 feet in a day.

Machine-saws for felling trees have been already described (p. 205).

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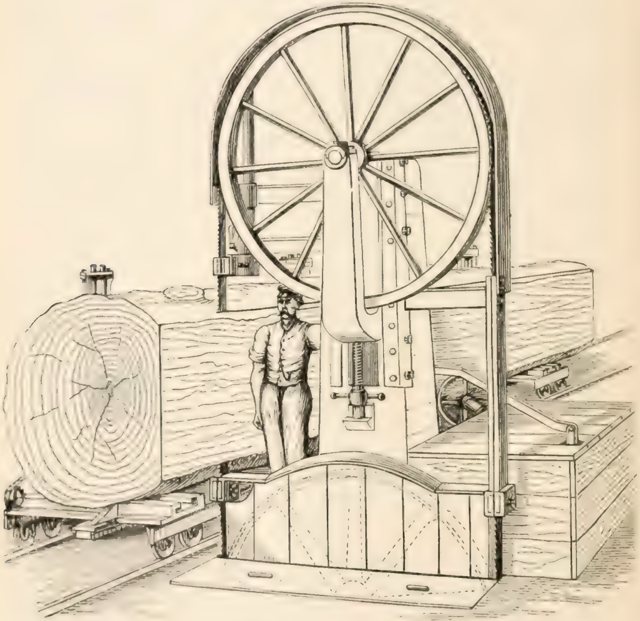
* Encyc. Brit., 1886, vol. xxi., p. 345.

† For a good description of an American saw-mill, vide Encyc. Brit., vol. xxi.

SECTION IV.—OTHER WOOD-WORKING MACHINES.

Besides saw-mills, other wood-working machines consist of veneer-saws, and machines for veneer-cutting, planing, boring, mortising, moulding, &c., by means of which all the finer kinds of joiner's work may be effected. It would, however, take the forester too far, to give full descriptions of these machines, and a short sketch only will be here attempted.

FIG. 308.



1. *Saws, &c., for cutting Veneer and thin Boards.*

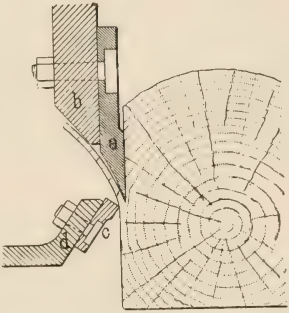
Veneer-saws differ from other frame-saws by working horizontally with their teeth pointed downwards. The wood to be sawn is fixed in a vertical frame, the feed being of an ordinary nature, except that it is from below upwards.

Veneers are sawn from planks of valuable wood, which are frequently glued to ordinary coniferous planks and then placed in the frame. The valuable wood can then be entirely sawn into veneer without any waste, the thinest veneers sawn being 7 to a centimeter.

For a number of years past veneer has been cut in machines.

[A machine for cutting thin boards was invented in 1875 by Léon Plessis,* the action of which may be understood from fig. 309: (*a*) is the cutting blade, 3 or 4 meters long, fastened to a frame (*b*); (*c*) regulates the thickness of the cut pieces of wood, which may vary from 2 to 20 mm. The greatest thickness which can be cut is 2 centimeters, supplying boards for cigar-boxes, packing-cases, &c. The instrument slides up and down in a vertical frame, a piece of wood being cut at each down stroke, and the butt which is being cut advances through a space equal to the thickness of the section at each up-stroke. The cutting part of the machine weighs 6 tons. The butts cut are as long as the cutting-blade, and are previously steamed, the wood being chiefly softwoods, such as poplar or alder.

Fig. 309.



The pieces when cut are pressed dry by hot rollers; they are then replaced consecutively so as to reproduce the form of the butt from which they were cut, when they are fastened together and kept ready for use.

This machine is driven by 20 horse-power and cuts in a minute 20 pieces, 3 meters long and of any thickness up to 2 c. It can cut 30,000 sq. feet of boards in a day.†—Tr.]

2. *Planing-Machines.*

Planing-machines consist of rapidly rotating, narrow, steel rollers, which are cut in various patterns along their length, and thus plane the surface of wood exposed to them in various shapes. They are constructed in various ways; some planing flat surfaces and others giving different profiles to the wood, some of them plane all four sides of a piece of wood during one operation.

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* *Société Française de tranchage de bois.* 4, Passage Charles Dallery, Paris.

† *Boppe,* op. cit.

By their means joiner's wood of all kinds is prepared, door and window mouldings, corner pieces, mouldings for picture-frames, &c., and wood is now brought at once to the market ready moulded from Sweden.

3. *Irregular Moulding-Machines.*

Machines used for irregular moulding resemble planing machines in principle; in their case a sharp steel cutter, revolving on a vertical axis, cuts wood which is pushed against it on a steel table into various shapes more or less out of a straight line, or irregular. They are used in making curved parts of furniture, wooden heels for boots, &c.

4. *Other Machines.*

Besides the above most important of the wood-machines, there are machines for **boring**, by means of revolving augurs; **mortising** when the augurs move laterally besides revolving, thus cutting oblong holes in the wood; preparing chips for **wood-pulp**, &c. Several machines for splitting fire-wood are largely used in German towns.

A consideration of the number of wares which are prepared by these various wood-machines, and above all of the enormous* quantity of planking and scantling turned out by saw-mills, and of the present demands of the market for quality, shape, and good external appearance of lumber, will prove the great importance of these machines in forest utilization.

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* "One saw-mill at Bay City, Michigan, which was burned before 1886, produced annually 40,000,000 feet of lumber besides shingles, laths, &c., from the refuse wood. The total yearly production of saw-mills in the United States is about 26,000,000,000 feet." Encyc. Brit., 1886, vol. xxi.

CHAPTER III.

WOOD-CARBONISATION.

SECTION I.—GENERAL ACCOUNT.

WHENEVER wood is burned, in the presence of air, it is converted into gases with a small ash-residuum. If, however, air is excluded and the wood heated to temperatures of 300°—350° C. (570°—660° F.), it becomes converted into secondary products, such as water, acetic acid, wood-alcohol, tar, carbon-dioxide and monoxide, and hydrocarbons; also into hydrogen and a solid residuum, wood-charcoal.

This decomposition of an organic body is termed **dry distillation**, and in the case of wood, **carbonisation.**

Charcoal consists of carbon and the incombustible inorganic constituents of wood: all charcoal also contains more or less hydrogen and oxygen, which become the more reduced in quantity the higher the temperature at which the wood is carbonised; consequently the percentage of carbon is then increased.

As the secondary products absorb a not inconsiderable quantity of carbon, and when charcoal is made in the forest some wood is actually burned, the loss of combustible matter, according to v. Berg, may be as high as 64%. This loss is, however, compensated by the superiority of charcoal to wood as a combustible and by its easier transportability.

Charcoal is more effective than firewood, owing to the greater intensity of the heat it gives off when burning, the greater power of radiating heat which it possesses, the facility with which it may be reduced in size before being used and especially owing to its superiority for metallurgic processes (greater uniformity in smelting, &c.).

Theoretically, according to Grothe,* charcoal should yield

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* Die Brenn-materialien u. Feuerungsanlagen.

7,440 heat-units, and wood 4,182. Its comparative facility of transport is proved by the fact, that the weight of charcoal is only 25% of that of the same volume of wood. Owing to these advantages, large quantities of timber in remote forests, which were formerly not otherwise utilizable, were converted into charcoal. Forests formerly existed in which the whole annual yield of wood was converted into charcoal and used for smelting iron, or in glass- or salt-works. In Europe at present, charcoal-making has lost much of its former importance, as nearly all heating and smelting processes are effected by means of coal and coke. A considerable quantity of charcoal is, however, still prepared, as the following figures show:—

	Imports in cub. meters (1893).
France	44,300,000
Italy	10,600,000
Spain	30,000,000

Austria-Hungary and Germany each exported in the same year 20,000,000 cubic meters of charcoal.

Charcoal-dust is used in the manufacture of the well-known briquets for fuel.

There are three modes of charcoal-making, in **pits**, **retorts** and **kilns**. Charcoal is usually made in kilns, so that only a few remarks will be made about the other methods.

The most wasteful way of making charcoal is in **pits**. A circular hole is dug in fairly stiff soil, with inclined walls and a depth of about a yard, it is then filled with dry branches. These are fired and remain burning uncovered until they have ceased to smoke and the wood has been converted into charcoal, which is then pressed down and dry wood placed upon it. The operation is repeated until the pit is full of glowing charcoal. It is then covered with sods and earth, and the charcoal allowed to cool; in 1 or 2 days the pit may be opened and the charcoal removed. This method which admits air almost freely, is only justifiable where wood has scarcely any value.

Charcoal-making in retorts is practised when wood is placed in completely air-tight masonry, or iron, chambers and heated, partly from outside by a furnace, and partly by the combination of carbon and hydrogen with oxygen within the chamber. As the construction of the chambers and the transport of the wood are very costly, and the yield of charcoal is not always greater than in kiln-burning, the method is only exceptionally employed, and then chiefly to obtain secondary products, acetic wood, tar, &c. Where wood-gas is used for illumination, charcoal is a bye-product.

SECTION II.—CHARCOAL-KILNS.

A charcoal-kiln is a heap of firewood of a regular shape, and with a covering, as effective as possible for keeping the fire inside the kiln and excluding atmospheric air.

The shape is generally that of a **paraboloid,** and only in certain cases that of a **horizontal prism.** Wood may be piled in kilns either vertically or horizontally, and as these methods of piling the wood, as well as the external form of the kiln, give rise to considerable differences in the process of charcoal-making, **vertical** and **horizontal kilns** will be separately described.

In **vertical kilns,** the wood is piled nearly vertically around stakes in the middle of the kiln, so that the latter assumes the shape of a paraboloid. **Horizontal kilns** are distinguished from the former kind by their prismatic shape and by the fact that the charcoal is removed from them gradually as the wood becomes carbonised.

Although the comparison between these methods will follow at the end of the chapter, it may here be mentioned that the vertical arrangement of the wood is that usually followed as experience shows that it gives the best results. A further distinction depends on whether the kilns are made in the forest, and consequently in different places every year as the felling-areas change, near iron-furnaces and other works using charcoal, or in large kilns away from the forests.

It is evident that in the last case greater care can be taken and better results will follow than when kilns are burned in the forest, frequently under very unfavourable conditions. In spite of this disadvantage, however, forest charcoal-kilns are more economical, as will be seen hereafter.

1. *Paraboloidal Charcoal-kilns.*

There are two methods of making charcoal which do not differ much from one another—they are the **common method** and the **Alpine** or **Italian method.** The former is practised all over Central and Western Europe, except parts of Styria, the Tyrol, Lower Austria and Lower Bavaria.

(a) The Common Method of Charcoal-making.

i. *Wood used for Charcoal-making.*

Charcoal-making is a much more important industry in mountain-districts stocked with coniferous forest than in broad-leaved woods. Whilst in the latter—only the less valuable firewood, round billets from early thinnings and stump-wood are carbonised—in coniferous forests, frequently the best class of firewood and even timber may be used for this purpose, according to the demands of neighbouring works for charcoal.

Any species of wood may be carbonised, but the method employed varies with its density and greater or less combustibility. If two kinds of wood are placed in the same kiln, one of which must remain some time burning in the kiln until the other is carbonised, the former might be burned to ashes before the latter can be removed. It is therefore advisable to pile only one species of wood at a time in a kiln; if different species must for any reason be burned in the same kiln the precaution should be taken to restrict these to hardwoods or softwoods only, or to split the harder woods and place them in the centre of the kiln, where the heat is greatest. It is, however, always better to separate the woods, as charcoal made from different species is used for different purposes.

As regards the comparative soundness and dryness of wood for charcoal-making, it is customary to use only sound air-dried wood, and not dead wood. Rotten wood is useless for the purpose, and must be carefully excluded. Carbonising broken billets is a difficult process, as the pieces continue to glow for a long time and may set fire to the kiln during the removal of the charcoal.

All wood for carbonisation should be spread out in dry parts of the felling-area or of landing depots until it is air-dry, in order that there may be the least possible waste of heat in driving off moisture from the wood. Only in very hot summers, or when the wood is highly resinous, is it advisable to use somewhat green wood so that the process may not be too rapid, or else the workmen may not be able to keep the combustion of the wood well in hand.

The shape and dimensions of the billets have considerable influence on the process of carbonisation. Although all parts of a kiln do not burn at the same rate, yet it is advisable to have the billets as uniform in shape as possible. As a rule, therefore, only one assortment of wood is used in a kiln; only in cases of necessity, in very large kilns or in carbonising stump-wood, should deviations from this rule be allowed.

One of the chief points of difference between the common and Alpine methods of carbonisation is that, in the former, the wood is generally split and used in small pieces, large pieces of sound wood being used in the latter.

The length of the billets may be either that usual for firewood, or a special length may be given to charcoal-billets (rarely exceeding 6 feet). The shorter the pieces the easier it is to give the kiln its requisite shape, and the less the cost of its construction. Excepting small round billets under 2¾ inches (7 cm.) thick, the wood should all be split and stump-wood should, as far as possible, be split into small pieces. This is especially necessary for broad-leaved woods, which burn slowly. In order that the wood may be packed closely, all snags and unevennesses should be trimmed off and fairly smooth, straight pieces set aside on the felling-area for charcoal-making. Crooked and bent branch-wood is only used in short pieces. In piling the kiln, besides the round and split billets, short little pieces of wood are used to fill interstices between the billets.

ii. *Shape and Size of Kilns.*

The usual shape of a kiln is that of a paraboloid, the volume of which is $\frac{d^2 \pi}{4} \times \frac{h}{2}$, where ($d$) is the diameter and ($h$) the height of the kiln ; or, as it is easier to measure the girth than the diameter of completed kilns, $\frac{g^2}{\pi^2} \times \frac{\pi}{4} \times \frac{h}{2} = \frac{g^2 h}{8\pi} = \frac{g^2 h}{25{\cdot}12}$ nearly. As, however, the shape of a kiln is usually not quite a paraboloid, but somewhat steeper and more pointed, 4—6 % may be deducted. Some useful tables* have been prepared for the cubic contents of kilns. It is easy to calculate the volume of a kiln whenever wood already stacked is used.

Kilns vary greatly in size in different districts ; sometimes, as in the Spessart, Thuringia, &c. they contain only 400—700 stacked cubic feet (12—20 st. cub. meters), whilst in the Harz they may be five times as large, and ten times as large in the Alps. Such large kilns, however, resemble those formed on the Alpine plan, in the common method a kiln of 2,000—3,500 st. cub. feet may be considered large and one of 400—1,000 st. cub. ft., small.

The size of a kiln is not without influence on the way it is fired, on the quality and quantity of charcoal and the cost of carbonisation. Small kilns require comparatively more fuel for kindling and more space than large kilns and also involve more work and supervision ; they are however more easily managed in the forest, the transport of the wood to them is less costly, they may be burned with less fear of firing and usually yield harder charcoal than large kilns.

It is difficult to say whether large or small kilns yield comparatively a greater or less percentage of charcoal for the amount of wood employed. Each district considers its own form of kiln the best ; in the Harz and Alps large kilns are preferred in this respect, and small kilns on the Rhine and in Franconia. The size of the kiln therefore is probably not an important factor in the question of comparative yield, which is chiefly decided by the skill of the burners. The size of the kilns in fact depends on whether every year large quantities of wood are carbonised or there is only a small local demand for charcoal, also on experience as to the comparative cost of large or small kilns.

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* Bohmerle, Tabellen zur Berechnung der Kubicinhalte stehender Kohlmeiler. Wien, 1873, Braumüller.

iii. *Site for a Kiln.*

The site for a kiln should be level, sheltered from winds, with water at hand, and either on the felling-area or close to it. Where several hundred stacks of firewood are to be carbonised there should be room for several kilns close together to save the cost of transport. The nature of the ground below the kiln has considerable influence on its rate of burning; if the soil is loose and porous it admits air to the interior of the kiln, which will burn rapidly; if heavy, the kiln will burn slowly. A sandy loam is most suitable, as it allows a moderate inlet of air, being at the same time porous enough to absorb the moisture which descends from a burning kiln. The soil should be of uniform nature under a kiln, in order that the inlet of air and the rate of carbonisation may also be uniform throughout.

A new site for a kiln is prepared as follows—the ground is freed from all sticks, roots and stones; the grass-sods are then dug up and the soil prepared as smoothly as for a garden-bed. The soil must be carefully freed from all stones likely to heat any part of the kiln excessively. The site is then carefully levelled, a stake driven in at its centre and a circular line traced as the boundary of the kiln. The centre is then raised 8—12 inches (20—30 cm.); the higher, the stiffer the soil and the harder the wood, the site being made to slope off from the centre in all directions towards the external circular line. This arrangement is intended to increase the inward draught of air and allow the liquids from the burning kiln to drain away, also that the piled billets may stand on an edge and not on their section. The site is then firmly trampled down and remains lying unused for some time, generally during winter, in order to settle and allow for any improvement which may be required. Before piling the kiln a heap of dry firewood should be burned on the site to dry it.

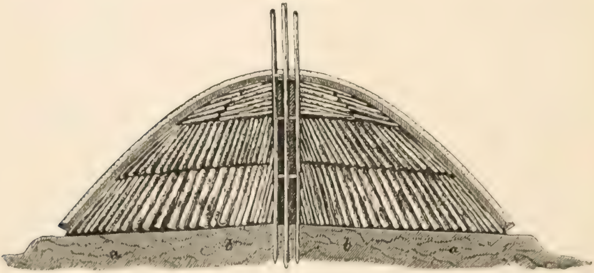
However carefully a new site may have been prepared, it is always inferior to one repeatedly used for kilns. The loss of wood in using a new site may amount to 10—17 or even 25 % (according to v. Berg). The charcoal-burners therefore always prefer old sites for kilns. In preparing an old site the same procedure is adopted as for a new site, and old refuse charcoal-dust is thoroughly mixed with the soil.

Although as far as possible suitable sites are chosen for kilns, yet in mountainous forests it is often necessary to make one on a slope, in a narrow gorge or other unfavourable place. An excavation is then made in the hill-side, and an embankment formed downhill so as to secure a horizontal site. It is then better to support the lower side of the site by wattle-work, or logs may be piled on one another and covered with earth to form the lower side of the site. Kilns made on sites like these always have a draught in one particular direction, which the burners must try to counteract by various devices whilst the kiln is burning. There must be round the kiln a cleared space sufficiently large for the burners to work in and affording room for the charcoal-burners to stack the wood, for a hut and so on.

iv. *Erection of the Kiln.*

At the centre of the kiln is a flue, which is constructed of three or four stakes driven into the ground about one foot apart. They are bound round with withes, forming a hollow shaft, which is filled with very dry, combustible firewood. The way in which the latter is inserted depends on whether the kiln is to be kindled from above or below. In the latter case a dry board is placed under the flue to keep back the soil-moisture; highly combustible fuel, such as pieces of resinous wood, shavings, birch-bark, &c. are then placed upon the board,

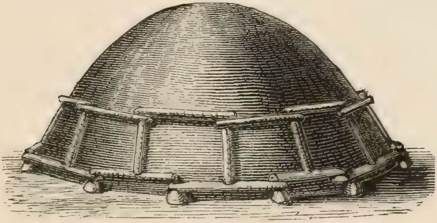
FIG. 310.



the upper part of the flue being somewhat loosely filled with broken branches, half-burned bits of wood, shavings, &c. When the kiln is kindled from above, the flue is filled in the reverse manner.

The flue once filled, finely-split pieces of dry wood and partly-carbonised billets are placed round it, the spaces between them being filled with wood-shavings, and then the regular kiln is constructed. This is done by piling two tiers of billets, the burner placing dry pieces of wood as closely as possible round the shaft, with their split sides inwards, followed by larger pieces, so that at a distance of about half the radius of the kiln the thickest pieces, which burn most slowly, are placed, and smaller billets outside these, as shown in fig. 310. After some progress has been made in the lower tier of billets, the upper tier is commenced and the two tiers continued together till the kiln has attained its full circumference.

Fig. 311.



If the kiln is to be kindled from below, a kindling-passage is left communicating with the flue; this is effected by placing a thick log on the ground from the opening in the flue to the edge of the kiln, which is gradually drawn away during the piling of the lower tier, leaving a hollow passage. The billets placed above this log should be somewhat shorter than the rest, so as to secure a level surface to the lower tier. This passage should always be exposed to windward, but is not required if the kiln is kindled from above.

When the two tiers of billets are piled the top of the kiln is filled in, as shown in fig. 310. For this the wood, which should be composed of small dry pieces, is laid very obliquely or horizontally. When the kiln is kindled from below, its whole top, including the flue, is thus covered; but when the kindling is effected from above, the flue runs through the top of the kiln.

Although the burners endeavour in piling the billets to place them as vertically as possible, as they are piled with their thick ends downwards they become gradually inclined outwards, so that eventually the outside of the kiln acquires a slope of 60° or 70°. This slope is necessary to support the covering of the kiln, being greater or less according to the state of the weather; during summer, in dry weather, it cannot be so great as in damp weather: whenever the covering does not dry very rapidly, a steeper slope is permissible.

The charging of the kiln is then completed by carefully stopping all openings and crevices with small split pieces of wood, in order to prevent too great a draught and save the covering from collapsing.

v. *Covering the Kiln.*

The next step is to apply the covering, which should be as air-tight and fire-proof as possible. Two coverings are applied, termed the **inner** and **outer coverings**; in order that they may not collapse they are supported by pieces of wood, termed the **upper** and **lower supports**. Every kiln requires at least the latter, which are formed of stout, short, forked pieces of wood driven into the ground all round the edge of the kiln; they may be replaced by a row of stones as big as one's head, on which split billets are placed contiguously in a circle a few inches from the ground for the covering to rest on and to admit air to the kiln. In some districts iron pieces are used shaped like circular segments with a support at one end of each piece; these are placed all round the kiln and are very durable.

The upper supports form a similar circle higher up the kiln, resting on vertical billets or forked pieces of wood; they are placed in position after the kiln is covered. In some districts a third circle of supports is added, but this is not usual.

The material used for the **inner covering** of the kiln consists of sods, leaves, moss, spruce or silver-fir branches, ferns, rushes, broom, heather, &c. Thin sods placed like tiles overlapping one another form the densest covering, and leaves or silver-fir branches also afford a dense covering. The covering is first applied to the top of the kiln, and should be thick enough to prevent the earth of the outer covering from penetrating through it.

The **outer covering** consists of a wet mixture of loamy forest soil and charcoal-dust, the remains of former kilns, for which fresh humus may be substituted. These substances should be thoroughly mixed with a hoe, freed from all stones and water added to form a stiff paste, which must have sufficient consistency to serve as a dense coating to the kiln without becoming quite crusted by the heat, remaining soft enough during the burning to yield without cracking to the gradual sinking of the kiln, and to allow the steam to escape.

This paste is first applied at the foot of the kiln, the upper row of supports are then placed over it and the paste continued up to the top of the kiln, being applied more thickly there than below. Sometimes a ring is left uncovered just below the dome of the kiln, this is covered with paste when there is no longer any danger of bursting. When the kiln is kindled from below, its lower portion is at first frequently left free from the outer covering, which is applied gradually as the burning proceeds; usually, however, the kiln is covered with paste before being fired.

After the kiln is covered, a wind-break is placed around it at a sufficient distance to allow room for the men to manage the kiln; it is usually made of coniferous branches at least as high as the kiln and fastened to stakes driven into the ground; this may be dispensed with in thoroughly sheltered places.

vi. *Kindling and Burning the Kiln.*

If the kiln is kindled from below, one of the burners applies a torch made of resinous wood-splinters through the kindling-passage to the kindling material at the bottom of the flue, which is thus fired. When kindled from above a little fire is lighted at the top of the flue. The kiln is always fired on a still morning before daybreak, sometimes whilst its base is open under the lower supports. If the fire has caught properly, the flue and its contents are first thoroughly burned and then the immediately adjoining wood, the fire rising to the top of the kiln. As soon as the dome becomes very hot, steam mingled with thick flocky smoke issues from it. At this period there is always more or less danger of bursting owing to the formation inside the kiln of an explosive mixture of air and combustible gases, or a sudden development of steam. Were such a misfortune to happen, the covering would be blown off and the arrangement of the wood disturbed. Too loose a soil under the kiln or too rapid burning may thus imperil matters, the risk of bursting being greater with dry than with slightly green wood.

After a few hours, the smoke acquires a pungent odour, a sign that the wood is being decomposed and that carbonisation is in progress. Charcoal is already formed in the dome of the kiln and the latter sinks down, carrying with it the covering which should adhere more or less firmly to it. If the carbonisation proceeds properly, a flame should issue from the top of the chimney in the form of a symmetrical cone, widening out more and more till flames protrude from the base of the kiln.

vii. *Mode of Conducting the Burning.*

The normal process of carbonisation just described cannot always be secured uninterruptedly. The draught is sometimes greater in one particular direction and the kiln itself is seldom uniformly built or covered, it may therefore settle down unsymmetrically or burn too quickly or too slowly. Charcoal-burners should know how to secure the kiln against these mishaps, and keep it burning in as normal a manner as possible.

This is effected by the following procedure :—the fire should be gradually led from the top of the kiln to its base, so that the kiln may settle down symmetrically and without burning the charcoal. The space left open at the base of the kiln, which is subsequently closed, may be re-opened if more draught is required and holes made in the upper part of the covering through which flames protrude in order to regulate the burning. On the second or third day after kindling, the first holes are made through both coverings down to the wood on the leeward side of the kiln. These are usually in two rows, somewhat below the flame at the top of the kiln. At first, the smoke issuing from these holes contains steam, but the nearer the combustion approaches the holes, the clearer, more pungent and pyroligneous it becomes; when it finally turns blue, it denotes that the charcoal is burning. Before the smoke turns blue, therefore, the upper holes must be closed with paste and a flat shovel, and a fresh row opened below the lower row. If burning proceeds too rapidly on any side of the kiln, all vent-holes must be stopped, the covering thickened and water applied if necessary.

By means of these simple arrangements, which require the burners' close attention, the wood in the kiln is gradually carbonised. When the carbonisation is nearly over, the fire is at the base of the kiln, ; holes are then opened there through which at length flames protrude showing that the burning is completed. The burners must now be on the watch to extinguish the fire at the right moment, and prevent any cracking or bursting of the covering by applying fresh paste or watering the kiln.

During the kindling process, the shaft of the flue, especially in its upper part, burns completely and leaves a hollow space in the kiln. Hollows may also form in other parts of the kiln owing to a defective site, to bad piling, kindling or control of the burning, or to the wood being too damp. If these hollows were not filled, they would cause a draught and attract the fire, the normal course of the burning would be hindered and the yield of charcoal reduced. Owing to the continual increase in size of these hollows, the covering might at length fall in and the kiln burst into flames. All hollows must therefore be promptly filled with short pieces of wood or large pieces of charcoal.

The following method of filling hollows is adopted :—whenever the burners have noticed that owing to a marked collapse of the covering a hollow has been formed, and have placed the wood or charcoal required to fill it alongside the kiln, they should test the extent of the hollow by tapping the covering with a mallet. They then remove the covering over the hollow, press down the contents with a piece of wood and fill the hollow rapidly covering it again with branches and paste, and beat the covering into a firm condition. All vent-holes should be stopped at least one hour before filling a hollow, for a whole day afterwards the burning should be conducted without any holes in the kiln. The hollow made by the combustion of the chimney is filled on the first evening of the burning and must often be filled again on the second, third, fourth and even on the fifth evening. This top-filling is often required several times on the same day; in large kilns, as many as 15 to 20 top- and side-fillings may be required during the burning and several more whilst the kiln is cooling.

It is evident that filling hollows in a kiln must waste charcoal, as by opening the covering a draught is caused and the fire unduly stimulated; charcoal is thus burned owing to the flames breaking out, and in pressing down the contents of the kiln some of the charcoal is broken into small pieces. Filling cannot, however, be dispensed with; every endeavour should therefore be made to prevent the sides of the kiln from collapsing, and to reduce the number of indispensable fillings to a minimum.

viii. *Watching and Cooling down the Kiln.*

Every evening during the burning of the kiln, the burners should adopt proper measures to secure regularity in the burning. Places where the charcoal is already burnt should be beaten down with the mallet, any fillings which may be required should be effected, cracks which may have opened in the covering should be carefully closed and all holes closed if the weather is stormy. Frequent inspection of the kiln at night is necessary.

Towards the completion of the carbonisation, when the kiln has sunk considerably and the upper covering is very dry and cracked, it should be well beaten down and covered with damp earth, or watered, so as to exclude the air more and more. As soon as the lower covering burns and flames appear at the foot of the kiln, it is clear that the carbonisation is completed; all vent-holes must then be stopped and the whole surface of the kiln covered with damp earth. The kiln is then left alone for about 24 hours. Then in order to hasten the cooling, the burners remove the covering in strips and apply fresh earth to the glowing charcoal so as to fill up all crevices. This rapidly extinguishes the fire, an important point when the weather is dry. About 24 hours, as a rule, after this has been done, the charcoal may be removed.

ix. *Removal of the Charcoal.*

In order that the charcoal may be of good quality, it should not remain longer than necessary in the glow of the kiln. At the same time it must be gradually removed, so as not to set the kiln in a blaze. A commencement is made in the evening and the work continued all night, when any fire may be more readily seen: each night only a certain quantity of the charcoal is removed, according to the size of the kiln.

The method adopted is as follows:—the burner with a long-toothed iron fork opens the kiln on the leeward side, and removes as much charcoal as he can without setting the kiln in flames. The charcoal is laid on one side and usually watered, whilst the hole is filled with earth. The kiln is then opened at another place and so on all round, until there is nothing left but its centre consisting of small pieces of charcoal, earth and ashes, which are eventually raked out and allowed to cool.

Once the charcoal has been removed, it is sorted according to size, the smaller pieces being sifted from the ashes. What is left is mixed with the ashes, &c. and serves for covering the next kiln. The partly carbonised pieces may be kept for filling or kindling other kilns, or carbonised in small kilns specially made for the purpose.

(b) Alpine* Method of Charcoal-making.

The method of charcoal-making employed in many parts of the German Alps differs in some respects from the ordinary method. The Alpine kilns are usually in fixed places near river-booms, in timber-depots or at the base of an extensive mountainous tract. The wood thus carbonised is almost exclusively coniferous (chiefly sprucewood and less frequently that of larch and silver-fir) and is generally employed in round pieces 2 meters (6½ feet) long. The site for the kiln is prepared as in the ordinary method, except that it is quite flat, a wooden base being supplied to the kiln.

This base is formed, as shown in fig. 312, by placing split billets radially from the flue outwards, on them other pieces are placed sufficiently close together, so that all the wood to be carbonised can rest on them, but sufficient intervals are left for a draught of air.

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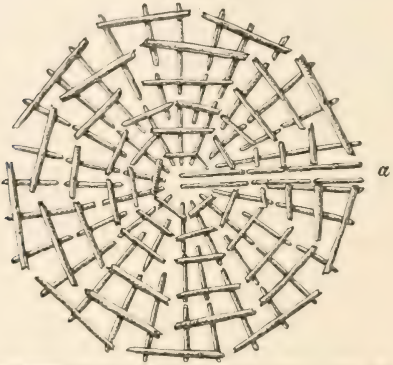
* [Also termed the Italian method, but Gayer states that Italians usually follow the ordinary method with kindling from above.—Tr.]

The flue is formed by three stout poles often kept in position by iron rings and is filled, as before, with kindling material. Piling the wood, on account of the size and weight of the pieces, is a heavy piece of work. It is formed of two tiers, and a dome with two thin layers of wood, and is from 5 to 6 meters (16—19 feet) high. The wood should be piled as closely as possible, all the larger interstices being filled with split wood. The kilns are usually larger than ordinary ones, but excessively large ones containing 1,500 to 2,000 cubic meters (50,000 to 70,000 cubic feet) are no longer made.

Fig. 312.

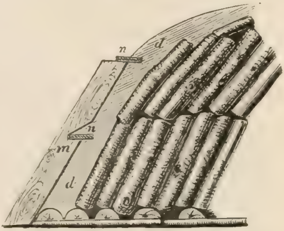


(a), represents a space left when kindling is applied from below, as in S. Bavaria.

As the heavy pieces of wood can be piled only with difficulty on the base of the kiln, a kind of wooden tramway or sledge-road is constructed, on which the pieces can be brought to the kiln in trucks or sledges. As a rule the kindling is effected from above, and for this purpose, a central cavity is arranged at the top of the kiln in which the flue terminates. When the large pieces of wood are all piled, the interstices are filled in carefully with small pieces of split wood.

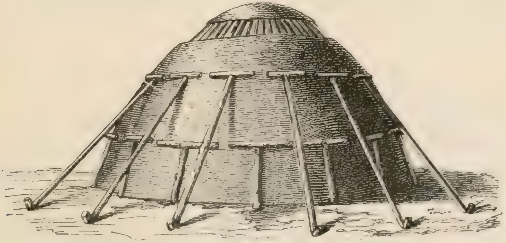
Alpine kilns are usually covered more thickly than common kilns. Ordinary material, if found close at hand, is used for the first covering; usually, however, only a single covering of mixed clay and humus is used, which must be very carefully spread over the wood. Special kinds of props are also used to support the sides of the kiln, which are at gradients of 60° or 70°. These props are either formed as in fig. 313 of planks (*m*) placed edgeways round the kiln, having niches cut into them at half their length, on which horizontal planks (*n*) rest to support the covering (*dd*).

Fig. 313.



Or stout T-shaped props are used as in fig. 314. The covering is first plastered on to the base of the kiln, then the lower props are applied and the plastering continued till the upper props are required; the dome is then completely plastered, at first only thinly so as to allow the gases to escape.

Fig. 314.



The kiln is kindled by lightly filling the still open flue with short thin pieces of split wood, on which comes a layer of glowing charcoal. As soon as the kindling material has thoroughly caught fire, fresh charcoal is from time to time heaped on. The split wood which for a time supports the charcoal burns completely, and the glowing charcoal falls to the bottom of the flue. The flue is then filled with charcoal, which is pressed down, and the kindling cavity also filled with a heap of charcoal. After a few hours the flue is burned through from below, and must be repeatedly filled, as long as the glowing charcoal continues to sink. When all danger of explosion is over and the wood in the dome is thoroughly kindled, it is covered with paste, and the burning henceforth conducted as in ordinary kilns.

In Alpine kilns the filling which has just been described must be most carefully conducted; as a rule, only charcoal is used for the purpose.

This method then differs from the ordinary method of burning kilns, in the following points:—

(i) The large dimensions of the pieces of wood to be carbonised and the fact that they are not usually split.

(ii) The wooden base of the kiln to cause a draught of air, which is required owing to the large pieces of usually green wood which are being carbonised.

(iii) The large dimensions of the kilns.

(iv) Only one covering being applied to the kilns, which is usually thick and requires special supports.

(v) By the special mode of kindling employed, which is usually, if not always, from above.

2. *Kilns with Wood piled Horizontally.*

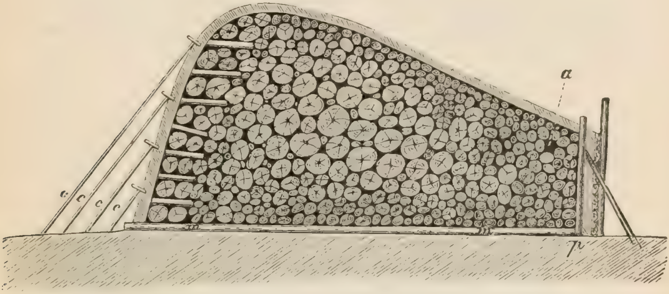
In Sweden and Austria, wood to be carbonised is piled horizontally, but the practice is becoming less frequent than was formerly the case. The following are the chief points of difference between this and the ordinary method.

(i) The wood carbonised is chiefly coniferous; the pieces are round logs, barked if possible, and of various dimensions up to 20 feet or (in Sweden) 26 feet in length. The pieces of wood must be quite straight, or they could not be densely piled. As such large pieces may be used for timber, the method is employed only in localities where the timber of the species in question is unsaleable.

(ii) The site chosen for the kiln is usually on slightly inclined ground, but otherwise of a similar nature to that described for ordinary kilns. It is also similarly prepared, but often is merely levelled, covered with earth and firmly beaten down.

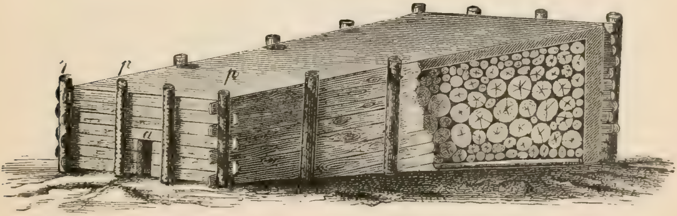
The size of the kiln should also be considered, its breadth being the length of the pieces of wood and its length varying, (usually 13 to 20 feet, but often 25 to 40 and even, according to v. Berg, 60 feet). The site should be a long rectangle, the longer side of which has a slight gradient.

Fig. 315.



(iii) In piling the wood, the first point is to make the base of the kiln ; it consists of three long straight poles which are placed on the ground at equal intervals, lengthways as regards the kilns (fig. 315, *m m*). At the lower end of the kiln stout stakes are driven into the ground (figs. 315, 316, *p p p*), and the piling commences against these stakes. As in the figures, the thickest wood is placed in the middle of the kiln and near its upper extremity, while the smaller pieces are placed above, below and at its foot.

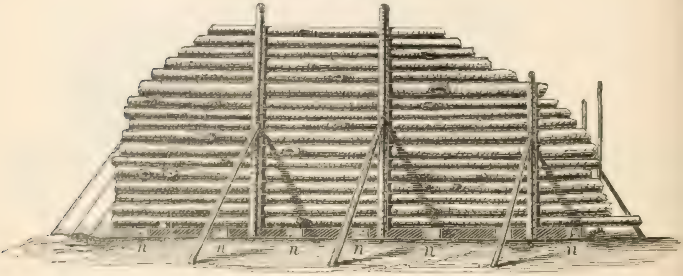
Fig. 316.



The wood should, in this case also, be piled as closely as possible, and interstices filled in with split wood. The flue is formed, as may be seen from fig. 315, *a*, by placing several logs around a cylindrical hole running from side to side of the kiln, or as in fig. 316, *a*, a kindling chamber is left open, as is customary in Steiermark.

(iv) The kiln is now covered; the inner covering is usually spruce or silver-fir twigs, the lower ends of which are stuck into the wood so that they overlap one another like tiles. The outer covering consists of a similar plaster to that used in ordinary kilns, or the same mixed with damp earth.

FIG. 317.



In order that this plaster may adhere to the vertical walls of the kiln the latter are supported by poles placed 6 to 8 inches apart along the two sides of the kiln, and its front (fig. 317), or in Steiermark the whole kiln, is surrounded by planks (fig. 316) resting on horizontal logs (*n n n*, fig. 317) to secure a draught of air. The plaster is applied between these planks and the ends of the logs, and is rammed down. The back of the kiln is in Sweden supported by props (*c c c*, fig. 315). The roof is at first only thin, and is thickened after the kiln has been fired when there is no longer any danger of its bursting.

(v) In order to fire the kiln the kindling flue or chamber is filled with readily combustible material, the filling being continued with an open flue until the kiln is thoroughly fired. The whole front portion of the kiln must burn if the fire is to continue uniformly throughout. Once this has been secured the kindling flue or chamber may be closed, and the combustion continued by opening successive vent-holes in the roof (in Steiermark also in the sides of the kiln), as in the ordinary method.

Carbonisation proceeds obliquely backwards, the fire being always more advanced towards the roof than at the base of the kiln. Thus the base of the back of the kiln is the last to be carbonised, and the process is completed as soon as flames emerge from vent-holes there. The charcoal is cooled by removing part of the roof and putting earth on it, the walls not being opened.

(vi) The charcoal is first removed from the front of the kiln. A portion is removed daily, and the kiln closed again.

In Steiermark a commencement is made by removing the charcoal whilst the back of the kiln is still burning. As the front part of the kiln burns longest, and the charcoal there becomes light, attempts are made to prevent this by its early removal. It should, however, be remembered that this frequent opening increases the draught, and must cause a considerable loss of charcoal.

SECTION III.—PROPERTIES OF GOOD CHARCOAL, AND YIELD OF THE DIFFERENT KINDS OF KILNS.

1. *Properties of Good Charcoal.*

Charcoal is a dry, more or less lustrous, porous and fairly hard substance, of low specific gravity, without taste or odour. Different kinds of charcoal, however, show some variations in these respects which modify their relative value.

(a) **Specific gravity.**— The specific gravity of charcoal is directly proportional to that of the wood from which it is made. Thus, heavy, broad-leaved woods yield heavier charcoal than coniferous softwoods. The amount of moisture in the wood also affects the specific gravity of the resulting charcoal, dry wood yielding charcoal of a higher specific gravity than green wood. The rate of burning is also influential, quickly burned kilns yielding lighter charcoal than kilns slowly burned. This results from the fact that with a quick fire more charcoal is expended in producing tar, &c., than where the chief process is merely carbonisation. Considering the wide range of specific gravity for wood of one species of tree, and the variable amount of moisture it may contain as well as different rates of burning, it is evident that there must be a considerable range in the specific gravity of charcoal.

Klein states that the specific gravity of charcoal ranges from 0·14 to 0·20, also that green wood loses 70% to 75% of its weight during carbonisation, so that the weight of charcoal is from 25% to 30% of that of the wood from which it has been made.

(b) **Appearance of charcoal.**—Good charcoal should be black, with a steel-blue, metallic lustre and a conchoidal fracture. When too long burned charcoal is dark black, without lustre; if insufficiently carbonised, reddish (foxy), although v. Berg states that occasionally, during dry weather and under other circumstances, perfectly good charcoal may have a reddish colour. When dark black and dull, charcoal is soft, friable and has been overburned. Good charcoal when struck gives a metallic sound, which is clearly apparent on shaking a basket full of it, whilst overburned charcoal gives only a dull sound.

(c) **Absorption of moisture.**—Charcoal is extremely absorptive of all liquid and gaseous bodies, many economic uses being founded on this property. From a forester's point of view this property of charcoal is highly important if it be sold by weight, as the absorption of water makes it heavier than before. It does not appear to increase in weight by more than 8—12% by absorbing moisture from the air, but by direct contact with water its weight may in a few minutes increase 25—30%, according to its greater or less porosity, and this may increase to 60—120% after 8 hours immersion in water. A large proportion of absorbed water subsequently passes off as vapour.

(d) **Heating-power.**—A good charcoal should burn without flame or smoke, and give out a more or less prolonged, intense heat. When it has been under-carbonised, charcoal burns with a flame, whilst overburned charcoal is reduced to ashes more quickly than good, heavy charcoal rich in carbon.

It is clear that a cubic foot of wood gives out more heat than the charcoal which may be made of it, as much carbon and all its hydrogen are abstracted in the by-products during carbonisation. This loss is about 40%, or the heating-power of the wood is to that of the charcoal made from it, as 100 : 55 or 60. But the volume of the charcoal is hardly half that of the wood which produced it, so that charcoal, volume for volume, is more heating than wood. Besides, the heat given out by charcoal is more lasting than by wood, and it radiates heat more intensely. These facts explain sufficiently the higher economic value of charcoal than wood as a heating agent.

(e) **Summary.**—A good charcoal may therefore be recognised by the following properties: it must be thoroughly burned without being brittle and show the woody texture distinctly; its fracture should be conchoidal and lustrous, quite black and yet it may be touched without blackening the hands; it should have few cracks, and give out a clear sound when struck. As regards the inherent qualities of good charcoal, it should have a high specific gravity, burn slowly without flame or smoke and radiate a strong, enduring heat.

Bertier and Winkler state that the heating-power of charcoal made from different woods does not vary much if equal weights are used. As regards equal volumes, heavy charcoal gives out more heat than light charcoal. The amount of ash contained in charcoal is usually small, and according to Violette, varies between 0·6% and 3%, according as the wood is taken from young or old parts of a tree, and is in fact the same as that of wood from which the charcoal has been made.

2. *Yield of Charcoal.*

In discussing the quantity of charcoal which a certain volume of wood may be made to yield, the following points should be considered:—**the kind of wood, situation of kiln, state of weather, process and duration of burning, and different methods of carbonisation.**

(a) **Kind of wood.**—All wood on being converted into charcoal naturally shrinks. Dry wood shrinks less than green wood, and consequently gives a larger return. Large pieces of wood also yield in volume more charcoal than small pieces, as more of the former can be piled in a kiln.

Klein gives 21·6% charcoal for coniferous wood, and 25·4% for broad-leaved wood as the shrinkage in girth after carbonisation. V. Berg found a shrinkage of only 12% in length for billets 2 meters long.

(b) **Situation of kiln.**—The nature of the site of a kiln has an important effect on the yield of charcoal, a new site yielding less than one repeatedly used.

(c) **State of the weather.**—The weather has important effects on the yield of a kiln. Uniformly still weather, which frequently occurs in late summer and autumn, is best; changeable weather, accompanied by storms, is most unfavourable. Prolonged dry weather is as unfavourable as continual rain: in the former case the covering is liable to crack, in the latter it may burst or the process of carbonisation be too prolonged.

Although in some Alpine districts charcoal-making continues throughout the year, even during winter; as a rule it is carried on only during summer and autumn, when experience shows that the greatest yield is obtained.

(d) **Process of burning.**—It is evident that the yield must be reduced when the cooling down of a kiln is more than usually prolonged, and the charcoal exposed to a greater total amount of heat than is really necessary. The burner, except under certain unforeseen circumstances, can control the cooling process if he piles the wood correctly, distributes the pieces in different parts of the kiln according to their size and specific gravity, and conducts the burning carefully. Slow, careful progress, especially during the earlier part of the burning, not only yields heavier charcoal but also a larger volume of it.

(e) **Duration of the burning.**—The length of time during which a kiln should burn is very variable and depends on its size, the dimensions and degree of dryness of the billets, the quicker or slower action of the fire (depending on the site, arrangement of the wood, weather, &c.) and many other circumstances. Small kilns with small billets will evidently burn more quickly than large kilns with large billets: in windy or moderately damp weather the burning can be effected more quickly than in still, dry weather.

Kilns of sprucewood containing 800—1,200 stacked cubic feet are carbonised in 6—8 days, beechwood in somewhat less time. Large kilns containing 4,000—8,000 cubic feet, in favourable weather, require about 4 weeks to burn, and in unfavourable weather 5—6 weeks. There is a considerable loss of charcoal when the carbonising process is driven too quickly.

(f) **Different kinds of kilns.**—The different methods of carbonisation yield different volumes of charcoal, but it is difficult, considering the extremely variable conditions in any case, to decide which method is most productive.

The yield in the **common method** varies according as the kindling is applied from above or below. Although in both cases the fire first develops at the top of the kiln, in kindling from above the fire never consumes the chimney so thoroughly and develops so well in the centre of the kiln as when it is kindled from below. Filling is therefore more difficult to effect in the former case ; hollows then develop which have to be repeatedly filled, a circumstance which must have bad effects on the yield. By kindling from below, the fire in the centre of the kiln, persisting from the first, gradually heats all the wood in the kiln : when, however, the kiln is kindled from above and the fire gradually descends, it constantly meets with cold wood ; this delays the process and reduces the yield. In many districts, therefore, and especially for hardwoods, kindling from below is preferred.

The **Alpine method** is usually applied only to coniferous wood ; the kilns are then exceptionally large, while they are burned for years on the same site. These circumstances have so much influence on the yield that it is difficult to say what are the direct effects of the method. The charcoal from Alpine kilns is not inferior in quality to that produced by the common method ; it may be lighter, owing to the repeated fillings of the chimney, but owing to the large size of the billets it yields larger pieces of charcoal than the latter. There is, however, a falling-off in quantity in proportion to the volume of wood burned as compared with the common method, owing to the fact that billets are green, and unsplit. A good deal of charcoal is also expended in filling the chimney, and the large billets remain exposed to the heat for a longer time than the smaller split billets in a common kiln ; this necessarily reduces the yield.

Horizontal kilns are employed only when timber can be spared for charcoal-making, they are therefore comparatively rare in Europe. The construction of these kilns and the process of burning are easier than in vertical kilns, there is no need for filling, while owing to the thick covering the weather has hardly any influence on the process; but in spite of these advantages v. Berg has shown that the yield is less than in vertical kilns. As the firing proceeds lengthwise in order that the ends of the logs may burn, one end of the kiln is exposed to the fire too long, and when the charcoal is removed at that end, air is admitted and much charcoal burned. This method therefore yields not only lighter charcoal but a smaller volume in proportion to the amount of wood than the others.

It therefore appears that the common method, with kindling from below, gives the best results. The comparative outturn of charcoal in quantity and quality, however, greatly depends on the skill and foresight of the burners, which is really the most important of all factors, as experience shows in the case of permanent sites of kilns where the burners are frequently changed.

(g) **General results.**—Charcoal may be measured by weight or volume, the latter being more usual and large baskets or rectangular measures being used for the purpose.

Coniferous wood yields more charcoal than broad-leaved species; soft, broad-leaved woods less than coniferous wood but more than hardwood. Branchwood and wood in the round yield less than split wood. The yield from horizontal kilns is often given as greater than that of common kilns, but these results are of doubtful accuracy.

The average yield from forest kilns may be considered good for broad-leaved wood with 48—50% by volume, and for coniferous wood with 55—60%.

V. Berg* gives the following percentages:—

Species of wood.	Volume.	Weight.
Beech or oak (split billets).........	52—56	20—22
Birch ,, ,,	65—68	20—21
Scotch pine ,, ,,	60—64	22—25
Spruce ,, ,,	65—75	23—26
,, (stump-wood)	50—65	21—25
,, (round billets	42—50	20—24
,, (small branchwood)	38—48	19—22

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* Anleitung zum Verkohlen des Holzes.

Beschoren * gives the following percentages as resulting from his experiments.

Species.	Volume.	Weight.
Oak	71·8	21·3
Beech	73	22·7
Hornbeam	57·2	20·6
Birch	68·5	20·9
Scotch pine	63·6	25

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* Grothe, Brennmaterialien.

CHAPTER IV.

DIGGING AND PREPARATION OF PEAT.[*]

SECTION I.—GENERAL ACCOUNT.

IN the cooler parts of the temperate zone there are numerous areas, frequently of large extent, characterised by an excessively wet soil and a specialised flora, and generally known as peat-moors or bogs. Most of these moors yield **peat**, sometimes called turf, as in Ireland and the English fens.

Extensive peat-bogs are found in all northern countries, but not in southern Europe. They are most abundant in Ireland, Russia and Germany, occurring in river-valleys, along the banks of lakes, on high plateaux and ridges in mountainous districts (such as the Harz, Thüringerwald, Erzgebirge, Rhone-valley, Schwarzwald, Alps, &c.), also on the high Swabian plateau in Bavaria bordering the northern declivity of the Alps, where there are at least 600 square miles of peat-bog; there are also extensive bogs in the plains of North Germany. This latter district, extending northwards into Denmark and westwards into Holland, is the richest peat-producing tract of land in Europe, for bogs over 1,500 square miles in extent, which occur in East Friesland, do not probably exist elsewhere. Germany is thus provided with a supply of fuel much exceeding that of all the German coal-fields.

[There are in Ireland 1861 square miles of peat-bog, chiefly in the counties of Mayo, Galway and Donegal,[†] but the area of bog in Great Britain is not given in the agricultural returns, though peat is dug for fuel in the Scotch and Welsh hills and mountains, in the Yorkshire and Lincolnshire Wolds and moors, and in the fens of East Anglia.—TR.]

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[*] One of the best works on this subject is: Hausding, *Industrielle Torfgewinnung*, Berlin, 1887, by Seydel.

[†] [The area of the bog of Allen in Ireland is about 370 square miles.—TR.]

Peat has been utilized from the earliest times, and owing to the high price of fuel in Germany from 1840 to 1870, its utilization was then considerably increased. The present low price of fuel has somewhat retarded measures which were being taken for improving the yield and preparation of peat, but it is still largely utilized in many countries and the question of converting it into improved fuel still attracts attention.

Much has been written at different times about the composition of peat; recently, Wiegmann, Sendtner and Braun all agree that it consists chiefly of vegetable substances, the decomposition of which is arrested by excessive moisture: the only questions still unsolved being whether the exclusion of air by water alone suffices to retard the decomposition of the vegetable remains, or whether the antiseptic action of free humic acid is also indispensable for this purpose, finally, whether frost in any way affects the formation of peat.[*]

Since, during the formation of peat, air is excluded by the presence of water in excess, the carbon contained in vegetable débris cannot be converted into carbon-dioxide, but plants in the deeper layers of a peat-bog part with their oxygen and become carbonised. The dark brown peaty mud imbedded between the remains of the plants consists of carbon and humic acid.

Permanent and excessive moisture causes the formation of peat, and this, according to Sendtner,[*] may be due to:—

(1) **A damp climate**, as in high mountainous regions.

(2) **Impermeability of the soil**, when the bed of a peat-bog is formed of clay, loam or marl.

(3) **The hygroscopic nature of the soil.** For only thus can the presence of peat be explained on slopes, such as below the summit of the Brocken, on the upper slopes of the Kniebis and in several places in the Alps.

In a forest, the accumulation of masses of undecomposed humus (heather-soil, alder-humus, &c.) often causes the formation of peat, humus being highly hygroscopic. Forest trees, which have been thrown by storms, snow, &c., and thus by their partial decomposition considerably increase the supply of humus, besides interrupting the natural drainage, frequently cause the formation of a peat-bog.

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[*] Vide: Sendtner, *Vegetationsverhältnisse von Südbayern*, p. 641; Sprengel's notes on pp. 37, 41 of Lesquereux, *Untersuchungen über die Torfmoore*; also Braun, *Die Humussäure und die fossilen Brennstoffe*, Darmstadt, 1884.

(4) **The porosity of the soil.** When the sub-soil consists of permeable sand or gravel (as in the case of several Dutch and North German bogs) the situation being low either on a level with a lake or slightly elevated above it, the soil is maintained constantly wet by the subsoil water.

(5) **Inundations,** when repeated annually and lasting for some time.

(6) Finally, **peat-bogs** once established cause water to accumulate and may gradually extend over adjoining land.

[Some European peat-bogs are of great age and contain remains of extinct animals (Irish elk, &c.) and of arctic flora, dating from the close of the Glacial Period.—TR.]

SECTION II.—DIFFERENT KINDS OF BOGS.

Peat-bogs vary considerably in appearance, being composed of different plants, and containing different kinds of peat. Thus, in North Germany, **high peat-bogs** (*Hoch-moore*), are distinguished from **fens** (*Grünlandsmoore*, or *Brücher*); in South Germany, there are high peat-bogs and **morasses** (*Wiesenmoore*), while Lesquereux classifies Swiss bogs as **super-aquatic** and **infra-aquatic**, corresponding to high peat-bogs and swamps.

1. *High Peat-bogs.*

High **peat-bogs** termed also **peat-mosses, peat-moors** or **wolds** are chiefly characterised by the prevalence of peat-moss (*Sphagnum*), and a dense growth of heath plants (*Calluna, Erica, Andromeda* and *Vaccinium*); in South Germany, also, the mountain-pine (*Pinus montana*) appears on these bogs. These plants grow gregariously on extensive areas and form most of the peat. Such bogs are characterised by a gravelly or clayey subsoil and by the convex arched shape of their surface.

Whilst the South German bogs owe their origin to a more or less clayey subsoil, in North Germany the latter is more permeable and water constantly permeates the bogs from the numerous watercourses. The flora of these high peat-bogs is the same in both cases. The arching of their surface (from which the term **high peat-bog** arises) consists in a gradual, upward slope from their margins towards their centre. This upward slope is sometimes inconspicuous, but often reaches 20 to 23 feet, or even 33 feet, as in the Ems-moor and in East Prussia. High bogs originate at their highest point from which they tend to spread in all directions; this is due to the hygroscopic nature of the moss (*Sphagnum*), so that water constantly flows from the margins of a bog, rendering the surrounding land swampy. In this way even permeable soil may become covered with peat, the bog consequently spreading. Most bogs in mountainous regions are high peat-bogs, fens being rare in such localities.

2. *Morasses or Meadow-bogs.*

Morasses, as in the Bavarian plateau, have a completely different flora from high bogs. In the first place there are no peat-mosses, heath-plants or mountain-pines; in their place, species of *Hypnum* and sour herbage appear which are their chief components, while stunted Scotch pines are here and there disseminated. High bogs are readily distinguished, even at a distance, by the appearance of the heather and red-tinted *Sphagnum*, but morasses resemble extensive sour meadows.

In the Bavarian plateau, morasses have a subsoil of boulders and gravel brought down from the mountains and usually covered by a thin layer of amorphous calcareous marl, termed locally *Alm* which forms an impermeable base for the bog. The surface of morasses is horizontal, and they are more frequent in low lands near rivers than in depressions among hills, where high bogs prevail; they are more extensive than the latter in southern Bavaria.

3. *Fens.*

The fens of the North German plain have much the same appearance as the morasses of the Swabian pleateau, as they are also formed of sour herbage, such as rushes, sedges, cotton-sedge (*Eriophorum*) and moss; but according to Sprengel, they do not yield actual peat, but a muddy humus which is dredged from them and rests on an impermeable clay-subsoil, so that they may thus be distinguished from the Swabian morasses.

These fens are found often of large extent, chiefly near the watercourses, but are much less prevalent in North Germany than the high moors.

[The fens in East Anglia when near the low chalk hills of that region, as at Mildenhall, sometimes rest on beds of marl formed of the débris of water-plants (*Chara*) incrusted with carbonate of lime from the brooks running into them, peat being also found on the Kimmeridge and Oxford clays. In all these cases, the vegetation resembles that of the fens and morasses of Germany. Professor Seeley states that in East Anglia, at the base of the layers of peat there are embedded forests of Scotch pine and yew separated by marine clays.—Tr.]

Although, as a rule, the different kinds of bog preserve their distinctive character, yet there are many intermediate forms. Thus fens and morasses may contain patches of high peat-bog, and frequently pass completely into the latter form, as in many North German districts.

Besides the above-mentioned kinds of bog, there are **seaside-bogs** and **forest-bogs**. The former are found on low lands along the seaside, which are either occasionally inundated by the sea or into which brackish water infiltrates, or they are caused by the damming of the mouths of rivers or small water-courses by the tides. Forest bogs are those in which a great number of trunks of trees in more or less good preservation (bog-oak, &c.) are imbedded. These trees are sometimes erect and sometimes lying horizontal [as at Sunningdale in Berkshire.—Tr.]. Both these forms of bog, however, come under one of the headings already mentioned.

The peat found in the different bogs varies greatly in its character, according to the degree of decomposition it has undergone, its greater or lesser contents of humic acid and carbon, the vegetable débris of which it is composed, and finally the comparative quantity of earthy material which is mixed with it. Some peat resembles lignite both in appearance and economic value, whilst other kinds can hardly be distinguished from slightly decomposed vegetable remains. So many bogs are intermediate to these extreme forms, that it is difficult to characterise even a few of them. They are frequently distinguished by means of the plants from which they are formed, such as heather-peat, moss-peat, wood-peat, sedge-peat, &c., but no true standard of quality can thus be obtained, as each variety may represent peat of every possible quality. The best way to judge of the latter is to consider the degree of decomposition of the vegetable débris, the degree of cohesiveness of the particles of peat and their density. In this way, the following kinds of peat may be distinguished :—

(a) **Amorphous** or **Black peat**, a dark brown or blackish peat with silky lustre on a clean-cut section, heavy, generally rich in carbon, when dry breaking with a conchoidal fracture. This peat is generally found in the deeper strata of a bog, and the plants of which it is formed are scarcely recognisable.

(b) **Fibrous** or **Brown peat**, of a loose, fungoidal structure, in which the component plants, grass, moss, heather, &c., are generally easily recognisable, it is usually of a lighter colour than black peat (yellowish to dark brown), less heavy, more or less carbonaceous, when dry does not crumble and usually occurs in the upper strata of a bog.

(c) **Dredged peat**, a more or less tenaceous black peaty mud, forming the lowest layer in morasses, showing no visible vegetable structure; when dry, it has a peculiar lustre and is heavy; owing to its muddy character it is generally moulded into various shapes.

Between dredged and black peat (the best kinds) and brown peat, there are numerous intermediate varieties, the quality of which is considerably modified by the amount of earthy admixture they contain. This earthy matter consists partly of the ash-constituents of the peat-forming plants, and is partly introduced accidentally by inundations, &c.

SECTION III.—METHODS OF HARVESTING PEAT.

Before undertaking to work a peat-bog, a full estimate should be prepared of its quality and its probable volume, in order to determine whether the outlay of capital expended in removing the peat will be covered by its value and that of the cleared land.

1. *Quantity of Peat.*

The following data are required to estimate the quantity of peat in a bog: the area, depth, amount of shrinkage of the dried peat and the loss of peat during its extraction.

(a) The **area** of a bog should be ascertained by surveying it.

(b) The **depth** may vary considerably at different points of a bog, which is not unfrequently intersected with one or more layers of sand, loam or trunks of trees. In order to become acquainted with the nature of the bog, it should be divided into a rectangular network, the points of intersection of which may be about 27 yards (25 meters) apart, and are marked by numbered stakes. Three methods can then be followed; either strong poles are driven down at each numbered point to the bottom of the bog, pits 2—3 yards broad are dug or a **peat-borer** is used.

Driving poles into bogs may lead to false inferences, if beds of marl or trunks and stumps of trees, &c. are imbedded and prevent the poles from reaching the bottom of the bog. Digging pits is often impracticable owing to the accumulation of water and always involves much labour and expense, but this method affords the best possible insight into the nature of the bog and must be employed to ascertain the quality of the peat. It is best to use the peat-borer, as this generally gives satisfactory results and saves much labour. Since, however, few bogs are level at the surface and their bed is often undulating and irregular, levels should be taken all over the surface of a bog, the levels of the bottom and top of each point of intersection being fixed with reference to a horizontal plane through the highest point in the bog. This levelling will show what is the contour of the bog, a knowledge of which is requisite before its drainage can be undertaken.

(c) With the help of the above factors, the contents of the peat-bog may be estimated in cubic feet. In order, however, to estimate how much marketable peat there may be, a deduction must be made for **shrinkage**. For as soon as a bog has been drained, it settles down and shrinks the more, the more thorough the drainage. The amount of shrinkage must be calculated by experiment.

Thus pieces of peat of the ordinary dimensions are cut from several trenches and thoroughly dried, their volumes being calculated before and after drying and the difference between them being the amount of shrinkage. This is generally from 30 to 50% of the volume of freshly cut peat.

(d) Finally the **loss of peat during extraction** must be estimated: this varies in quantity according to the skill of the workmen, the quantity of stumps or stems of imbedded trees and the cohesiveness of the peat; the better kinds of peat are much more brittle than inferior fibrous peat.

During frosty weather in winter, the walls of the open peat-trenches frequently crumble considerably; besides this waste, ridges of peat remaining between the trenches cannot frequently be utilized. Thus a loss of peat occurs, often 25 or 50% of its whole volume. If, however, this otherwise wasted material can be moulded into turves, no loss need accrue.

2. *Quality.*

The quality of the peat is ascertained in the above-mentioned manner, both as regards its efficiency as fuel, and the possibility of thoroughly draining the bog.

It has already been remarked that the quality of the peat varies in the different strata of the bog, the best peat being, as a rule, at the base of the bog and the inferior kind at its surface. In order to ascertain the nature of the peat throughout the bog, several experimental trenches are dug: the refuse is set aside and the fibrous peat stacked apart from the black peat, the relative proportion of each kind being calculated; the muddy peat at the base is then dredged out and each kind analysed.

As the value of peat depends on the quantity of combustible matter in it, which is greater the less water or ash the peat contains, the analysis is chiefly directed to ascertaining the quantity of water and ashes in the peat. The contents of the peat in bituminous substance and uncombined carbon, which is always a test of its value, may be found by extracting them with ether.

The value of a peat-bog also depends on the possibility of draining it. If a bog can be thoroughly drained within a year from the commencement of working it, the admission of oxygen from the air will more or less quickly convert the insufficiently decomposed and less valuable peat into rich black peat which is the most valuable kind. Well drained peat also crumbles far less than when the bog is undrained.

It is evident that if a bog is to be properly utilized, it should be worked in accordance with a fixed plan prepared beforehand; this plan specifies how much peat should be dug yearly, where the digging is to be commenced, in what direction it is to be continued, according to what principles it is to be drained and the best lines for transport. Wherever there is an intention of utilizing the peat and then converting the bog into a forest or meadows, so much of it will be dug each year in accordance with the purpose in view, to which the utilization of the peat is merely subsidiary.

If, however, it is intended to have a permanent supply of peat, only so much should be dug yearly as the bog produces in a year.

Fresh peat is produced regularly in all bogs where the conditions remain unaltered. Thus some bogs produce annually layers of peat 5 or 6 inches thick, or even thicker; others a mere film of new peat, and others none at all.

The first condition for a renewal of the peat is a drainage system by means of which the parts of the bog from which the peat has been dug can be properly irrigated. If these portions can be kept submerged continually, but not too deeply (about 2 to 4 inches), whilst here and there ridges and mounds remain above water-level, the water containing humus and the base of the bog not being completely freed from peat, a continual production of peat may be confidently anticipated. In order to secure these conditions, the useless upper layers of peat and other refuse are thrown on the cleared areas and trenches, care being taken to keep these latter inundated.

The mode of reproduction of a bog cannot be explained in a general manner, but only observed on individual bogs, whilst any change in the drainage of the surrounding land may greatly affect matters in this respect. As, therefore, a long period is required for such observations, during which changes in the water-supply may occur and the rate of production of peat vary in different parts of the bog, it is rare that working plans for a bog take into consideration its reproduction. It is, therefore, considered sufficient to prepare a plan for from 50 to 100 years, according to the extent of the bog, the demand for the peat and amount of labour available; a fixed quantity of peat is thus supplied annually, whilst the cutting proceeds in a proper direction. In the latter respect, it is customary to commence operations at the highest part of the bog, if it is intended that the peat shall be reproduced, and thence to proceed gradually to its lower parts.

SECTION IV.—DRAINAGE OF BOGS.

1. *General Account.*

Peat can be utilized only after a bog has been partially drained. It is chiefly small bogs resting on a sloping bed which can be worked without draining. Drainage is always necessary in the case of large bogs. The object is not to drain the entire bog, but only that portion which it is intended to work immediately and to such an extent that the peat may be readily dug and dried. The remainder of the bog should be kept thoroughly wet in all cases where the reproduction of the peat is intended, and also to protect the peat from being frozen *; this is also frequently useful when the land already freed from peat is to be cultivated.

All parts of the bog which are not being utilized should be kept thoroughly wet during winter, or the peat will be seriously injured by frost. When wet or damp peat is frozen it does not become compact again on being dried, but crumbles. If the cleared bog is to be planted with trees or converted into meadow-land, it is not advisable to drain the bog completely, but only to remove the superfluous water.

The method of draining a bog depends essentially on its situation and nature; one or other of the following methods being adopted:—leading water away in drains, cutting off the water-supply, collecting the water in drains or tanks, or causing the water to sink through an impermeable subsoil.

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* [Cranberry bogs in N. America are regularly inundated when threatened by frost, in order to protect the plants.—TR.]

2. *Ordinary Drains.*

The usual method of draining is to lead the water from the bog in ordinary open drains. It is then essential that some land near the bog is on a lower level than its bed; this generally occurs. The levels taken of the bog and the immediately surrounding country show the difference of altitude between the lowest point of the bed of the bog and that of the external land, and the gradient of the line joining these two points. This is the line of greatest fall, and should be the direction of the principal drain.

It should be noted that a steep gradient is desirable only outside the bog; within the bog the gradient of the drains should be less the more water the bog contains. Digging the principal drain is commenced at its lowest point outside the bog; it often suffices to continue this drain up to the bog, but, as a rule, it should be conducted to the lowest point within the bog. In case a brook runs through the bog it may often be used as the principal drain after some cuts have been made in it to improve the flow of water. If the bed of the bog slopes down towards a neighbouring river or brook, this slope affords the best gradient for the drainage. If, however, the bog lies in a depression surrounded by higher land, it is a question of expense whether to cut through the latter or construct a tunnel to serve as a drain. The dimensions of the main drain depend on the gradient and the quantity of water to be removed. It is not generally necessary to drain down to the bed of the bog. Too broad or deep drains often injuriously dry up the bog and are extremely costly both in construction and maintenance. Where the drain leaves the bog a simple sluice-gate should be constructed in order to retain sufficient water in the bog during winter. In the case of small bogs and drains, instead of a sluice-gate the inlet into the main drain is blocked in autumn with peat.

If there is much change of gradient in the bed of a large bog, several draining trenches are cut through the latter. It is often advisable to cut these drains from a certain point in the bog, and then lead them outwards in diverging directions, which generally cross one another at right angles.

Whilst the main drain is generally completed once for all, the subsidiary drains are dug gradually during the progress of removal of the peat. They are generally at right angles to the main drains and are intended to drain only that portion of the bog which is being worked. They are naturally smaller than the main drain.

In the extensive bogs of Holland, Friesland and Bremen the main drains serve not only for drainage, but also for the purpose of communication by barges and conveyance of the peat; they are frequently 26 to 32 feet broad.

3. *Drains for Cutting off the Water from Bogs.*

There are frequently small watercourses which run into a bog, or water runs down a slope into it. If then trenches can be dug so as to cut off the water-supply from the bog, they are very serviceable as an aid to ordinary drains, but will not alone suffice to drain the bog.

4. *Collecting-Drains and Tanks.*

A large number of bogs are supplied with water by infiltration from neighbouring watercourses. If then the bog lies above the level of the water it is possible to drain it in the ordinary manner; this cannot be done if it is on about the same level as the water. More extensive works are then usually required (which are too costly where peat-digging is concerned) in order to exclude inundations from the bog, or remove the water from collecting drains by means of pumps and hydraulic engines. Only when the inlet of water is inconsiderable can water which collects in the drains during the night be removed by manual labour. The construction of a sufficiently large tank near the bog to receive the water can be only exceptionally undertaken.

5. *Piercing an Impermeable Pan.*

If a bog should rest on a thin bed of loam or clay, below which is an impermeable stratum, or pan, of gravel or sand, the simplest method of draining it is often to bore or break through the pan and thus allow the water to sink below it. If, however, the shaft through the pan is made at the deepest part of the bog its drainage may be too thorough, and thus injuriously affect the peat.

SECTION V.—HARVESTING THE PEAT.

The removal of the peat may be effected in various ways. A distinction is thus made between peat dug by manual labour (*Stichtorf*), peat which is moulded into shape (*Modeltorf*) and peat removed and prepared by machinery (*Maschinentorf*).

1. *Peat Dug by Manual Labour.*

Only fairly compact peat can be dug by means of spades and the pieces, termed **turves**, are then dried in the sun and by exposure to the air. The different operations in this case are the preliminary works, and digging, drying and storing the peat.

(a) **Preliminary Works.**

(i) *Subsidiary Drainage.*

After the main drain and the most important side-drains have been dug, further subsidiary drainage must be done annually. This is effected by making a trench a little way from where the peat is to be dug, parallel to the line of digging and perpendicular to the main drain, so that either the whole or a portion of the area to be dug in a year may thus be drained. As soon as the season's digging is over, the junction of each of these drains with the main drain is closed in order to keep the bog sufficiently moist.

(ii) *Laying Out the Line for Digging.*

The area where the peat is to be extracted in accordance with the plan of operations, should then be measured and marked out with shallow trenches, so that the workmen may know where to dig.

As a rule, the peat should be dug in successive years from immediately adjoining areas and no wall of peat left standing between them, which is usually a sign of bad management though sometimes necessary where there is a superfluity of water. Each year's area should consist of a long, narrow strip, parallel lengthwise to the subsidiary drain. Such a shape allows a number of men to work simultaneously, renders drainage by means of a single trench possible and allows sufficient room for drying the turves, which are generally piled on a strip of land previously marked out and adjoining the digging trench. All vegetation should be cleared from this strip, so that the turves may be easily piled and thoroughly exposed to the air.

(iii) *Laying out Roads.*

The turves must either be dried on land adjoining the bog, or on the bog itself and then removed. In either case roads are necessary, which should be made on the driest part of the bog, be as permanent as possible and cross the drains only when this is unavoidable, in order to avoid the expense of bridges. Roads should be made of fascines and sifted gravel whenever they traverse wet ground. If the turves are removed in wheelbarrows from the digging-trench to the drying-ground, only a narrow pathway is required.

(iv) *Removal of Wood.*

On many bogs a certain number of trees are growing (mountain or Scotch pine, alder, birch, &c.), and their usually spreading roots often interfere considerably with the digging. These trees should be felled a year before the turves are dug, and their main roots extracted.

(v) *Management of Labour.*

Labourers employed in digging turves should be divided into parties, as in the case of forest work. According to the methods employed for digging and drying the turves, three, four or even more workmen form a party. The digging-ground is then subdivided into as many sections as there are parties of labourers, provided a certain length is not exceeded, in North Germany usually 2 or 3 yards (meters), and in South Germany 4 or more yards, per man. These measured lengths are staked out, numbered and distributed by lot among the parties.

(b) Digging the Turves.

i. *Season.*

It has already been stated that peat is damaged by frost, and this is the case both with uncut peat and turves. One or two degrees below freezing point is sufficient to do the damage. Frozen turves do not shrink after thawing, but dry the same size as when frozen; they are therefore very porous, form inferior fuel and crumble easily. Digging turves should not therefore commence until there is no longer danger from late frosts.

Although it may appear profitable to dig turves during dry spring weather, yet experience proves that a single late frost will damage the turves, so as to nullify all the advantage of early work. In countries therefore with a mild climate, digging turves should be commenced about the beginning of May, in mountainous and northern countries, from the middle to the end of May. The work should stop sufficiently early to allow the turves to dry thoroughly. This also depends on the local climate and especially on the humidity of the air. Digging turves generally terminates about the end of August, if the turves are dried out of doors. When they are dried artificially, the work may continue for a longer period.

ii. *Size of the Turves.*

The size of the turves depends on the compactness of the peat and the time required for drying them. The lighter and looser the peat, the better it holds together during digging and drying, the more quickly can the turves be dried and the larger they may be. In the case of black, amorphous peat, the turves are smaller than with brown peat.

iii. *Implements.*

All the implements used for digging turves are modifications of the garden spade.

The Frisian spade (fig. 317) is used for digging vertically; the spades (figs. 318, 319) are used for digging horizontally, they have short handles, but very sharp and perfectly flat blades. The peat-spade (fig. 318) is in common use. Fig. 319 is a two-bladed spade with one blade at right angles to the other, in order to loosen the turves on both sides at once; it is used in the Rhine provinces. Fig. 320 is a spade used for vertical digging in Upper Bavaria, the turves being cut on all sides with it. Fig. 321 represents a spade used in North East Germany to remove the useless superficial turf and sods of earth. A three-pronged fork resembling an ordinary dung-fork is generally used for putting the turves into barrows or carts for transport.

Fig. 317.

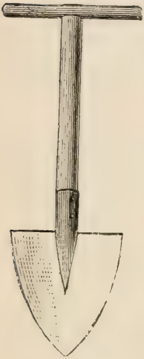


Fig. 318.

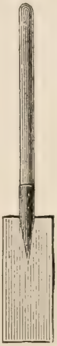


Fig. 319.

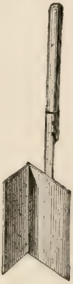


Fig. 320.

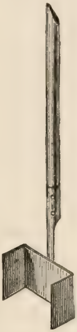
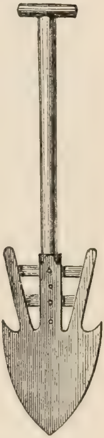


Fig. 321.



iv. *Digging Turves.*

There are two methods of digging turves, termed respectively the **horizontal** and **vertical** methods. The former method is almost universally employed in North Germany and is common in the Rhenish Provinces, and South Germany. The vertical method is practised in some Upper Bavarian bogs and in the Baltic Provinces. In the **horizontal method**, a workman beginning at the top edge of the wall of peat, cuts the vertical lines of a turf with the Frisian spade, whilst another workman standing in the trench, cuts the turf horizontally and sideways from the bank of peat.

In the **vertical method**, the workman standing on the top of the bank of peat cuts each turf free by one vertical or slightly oblique stroke of the spade (fig. 319) and tears it off from below, raising it with the same spade on to the bank of turf. As by this method the turf is broken off above and below, it has not a regular cubical shape; control is thus rendered more difficult, while there is more refuse from crumbling than in the horizontal method. At the same time the vertical method is less laborious and cheaper than the other. According to the skill of the workmen and the difficulty of cutting the peat, with horizontal cutting, 3,000 to 5,000 turves may be cut in a day, and with vertical cutting under favourable circumstances 6,000 to 7,000 turves. The vertical method is obligatory whenever the bog is insufficiently drained.

Before beginning to cut the turves the topmost layer of soil must be dug up in sods, as long or double the length of the turves, by means of the Frisian spade, or the spade shewn in fig. 321; these sods should be removed from the bog in wheelbarrows or carts.

The methods of cutting turves also vary, in the case of either horizontal or vertical cutting, according as the peat-bank is cut in **continuous** or **alternate strips.**

When the turves are cut in **continuous strips**, a commencement is made on the longer side of the area marked out for the year's cutting and strip after strip of peat is removed until the work has been completed. In this case, the work going on continuously down to the bed of the bog, there is either a vertical bank of peat left, or this bank may be in steps and the work proceed by cutting first from the top-most step, then from the second step, and so on. In this case the turves are removed from the bog as soon as they are cut, so as to leave room for the workmen to dig.

When the turves are cut in **alternate strips,** they are stacked close to the cut, like a wall, the strip on which they stand being left uncut and a new strip commenced immediately beyond it. In this case also, a deep bog cannot be at once cut to its full depth, but the work must be done in two operations. As soon as the stacked turves are dry and have been removed, the work of cutting the intermediate strips is undertaken.

Cutting in alternate strips is cheaper than in continuous strips, as a separate labour force is not then required for removing the turves to the drying ground; this method is also especially applicable when the bog is wet or insufficiently drained, also when it is superficial and can be cut in one operation. It has, however, the disadvantage that the turves are all from the same level and is not advisable for deep bogs.

v. *Obstacles to Cutting.*

Besides the water, which may prevent the cutting going down to the bed of the bog, various foreign bodies are imbedded in the peat forming so many obstacles to the digging; among these are stones, beds of sand or marl, roots and stems of trees, &c. Stones are frequently found in morasses and fens, besides interrupting the cutting they injure the implements. Layers of sand and marl often cause temporary flooding and must be cut through to let the water pass. Imbedded roots and stumps of trees are often serious obstacles in high peat-bogs. When these are stumps of resinous conifers, they are usually quite undecomposed* and must be completely removed. Large quantities of peat are sometimes wasted owing to the presence of stumps and long side-roots. Superficial roots of birch, alders, &c., in the upper layers of a bog are not so prejudicial, as they are generally rotten and can be severed with a spade.

Machines have recently been constructed, to replace manual labour in cutting turves, one invented by Browowsky† is used in North Germany, and cuts turves 3 to 6 yards long and $1\frac{3}{4} \times 2\frac{1}{4}$ feet in section, even from undrained bogs. These large turves are then cut into smaller sizes by manual labour.

(c) **Drying the Turves.**

As much care should be taken in drying as in digging turves, for their value as fuel depends greatly on the thoroughness with which they are dried. The air dries the interior of turves better than solar heat, which quickly hardens their surface but leaves them still wet internally. Turves may be dried either out of doors, or under cover.

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* In the Landstuhl bog, near Kaiserslautern, there are three layers of Scotch pine-stumps separated by peat, which yield annually 28,000 cubic feet of stump-wood. They are converted into tar.

† Hausding, *Indust. Torfgewinnung*, p. 25.

i. *Drying Turves out of doors.*

The drying-ground is either on the bog itself, or on an adjoining plot when the latter is too wet; as already stated it should be prepared before digging the peat. The turves are stacked in various ways, according to the space available for drying them, their comparative wetness and rate of drying, and the available labour-force; in order to dry them properly, however, they should always be turned over several times.

As soon as they are cut, the turves are usually removed by the workmen, either in wheelbarrows, or by the men forming a chain and passing them from hand to hand. They are then placed singly and on their edge, like bricks, at short intervals, or piled in little stacks of five turves each (fig. 322); or as in fig. 323 round a stake, up to a height of 3 to 4½ feet, a method usual in Swabia and around Lake Constance; or, as in some parts of Austria, stakes are driven into the ground with 9 or 10 pointed transverse sticks attached crosswise to their ends, on which the turves are impaled. After a preliminary drying, the turves are turned over once or several times, the lowest ones being brought to the top of the stack, and vice versâ.

Fig 322.

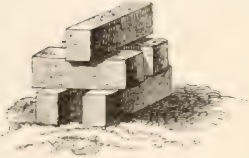
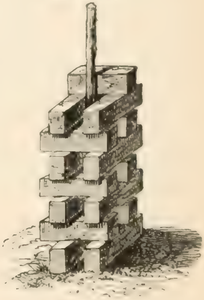


Fig. 323.



As already explained, when space is limited the turves are first dried on the top of the bank of peat, which is then cut in alternate strips. It is evident that the turves when stacked for drying do not dry so quickly or thoroughly as when placed singly on the ground. The lower turves must therefore be further dried on the drying-ground and for this purpose may be placed in circular rings of 5 or 6 turves on the ground, over which 4, 6 or 8 rings are placed, the space between two turves in a lower ring being covered by a turf in the ring above it.

When the turves are thoroughly dried—for which 4, 6 or 10 weeks are required, according to the weather, mode of drying and quality of the peat—if they are to be at once sold and removed, they are piled in the usual rectangular or conical sale-stacks, each containing 1,000 turves, or else in stacks similar to those used for fire-wood.

ii. *Drying under Cover.*

Sheds for drying turves are similar to those used for bricks, being very long and narrow and formed of laths which are covered with a light roof and in which the turves are stacked one above the other. These sheds offer the great advantage that the drying process is independent of the weather, but they are too expensive for general use.

Drying is, however, much more rapidly and thoroughly conducted in sheds, than in the open air, observations at Waidmoos having shown that in four weeks turves thus dried lost about 20% more moisture than in the open.

iii. *Shrinkage.*

From 70 to 90% of the weight of freshly cut turves is water; most of this is lost in drying, but air-dried turves still contain 26—30% of water. In passing to the air-dried condition, turves shrink considerably, the more so the better their quality.

Some peats lose 70—75% of their volume by shrinkage, so that a volume of 100 cubic feet of wet peat becomes only 25 to 30 cubic feet when dried. Fibrous peat on the other hand does not shrink much, but loses much more in weight than good peat, weighing frequently only one-fifth, or even less, of its weight when freshly cut.

(d) **Storage of turves.**—The turves cannot always be at once sold and removed, but must sometimes be stored through the winter. This is done either in the open, or in covered stacks.

The cheapest method is to pile the turves in either conical or prismatic stacks sloping at the top. Turves which are not thoroughly dried may, however, be easily spoiled in this way. The stacks should be erected in a dry and somewhat elevated place and carefully piled.

The turves are much better protected from damage when the stacks are thatched. Straw, reeds, spruce-branches or bracken will serve the purpose; better still, a light plank roof supported by four posts may be erected with a slope towards the rainy quarter, or the turves may be placed as follows—in the centre of a cleared space a strong stake is driven vertically into the ground, and billets placed radiating in a circle from the stake (as in the base of an Alpine charcoal-kiln) and covered with planks; the turves are then piled on this floor in a truncated cone thatched with straw. From these thatched stacks the turves can be taken during winter according to requirements, this can be done from uncovered stacks only at the risk of spoiling them.

Whenever the value of turves is sufficiently high, it is best to store them in sheds, which should have their greatest length perpendicular to the direction of the prevalent wind, and be lightly built of planks or laths, so that the wind may blow through them, the rain being kept out by a roof.

2. *Moulded Peat.*

Some peat is not sufficiently compact to be cut into turves, but must be moulded. This is the case with bogs containing much imbedded wood, or so dry that the peat crumbles into dust, or excessively wet so that the peat must be dredged; also where the peat is only ordinarily moist, but cannot be cut into turves owing to the presence of numerous undecomposed roots. In ordinary peat-bogs, however, where turves are cut, there is always a large percentage of waste peat resulting from the digging, drying or transport of the turves, which can only be utilized by moulding it. This waste frequently amounts to a fifth or a quarter of the annual yield of peat.

The different works in question are—preparing the peat, and moulding and drying the turves.

(a) **Preparing the Peat.**—Peat which is to be moulded should form a homogeneous mass, containing a suitable amount of water, and capable of being kneaded. If the peat is naturally powdery and dry, it should be mixed with water in a pit or a wooden bin with holes in its base ; if it is muddy peat with a superfluity of water, it must be dredged out of the bog with a hollow shovel or in a purse-net, and poured into the bin or on straw laid on the ground, so that the superfluous water may drain away. In whatever way it is collected, the mixed peat and water must now be thoroughly kneaded and worked together until they form a fairly homogeneous mass. This is generally done by men trampling on it with bare feet or with flat clogs, less frequently with the help of hoe or spade.

When the peat is of the ordinary consistency and moisture, the workmen place planks in the trench in front of the bank of peat, and cut the peat away from the bank with a sharp cutting mattock, letting it fall on the planks, and watering it sufficiently by means of wooden buckets. In Holland and several places in North Germany (especially Hannover), the peat-pulp is left alone to dry for a few days, and then again kneaded. In South Germany, it is moulded while still very wet, the second operation being omitted.

(b) **Moulding the Turves.**—The turves should be moulded at a place close to where the peat has been dried. If this is at any great distance from the bank of peat, the peat-pulp is removed in baskets or bins which are placed on wheelbarrows ; it is then thrown on to straw or planks, and is either cut or moulded into shape, the moulds containing several compartments or being similar to those used for brickmaking.

Peat-pulp is cut into shape in Holland, Friesland or Hannover, being spread out in layers, often half an acre in extent, and beaten flat with flat wooden shoes, planks or shovels. The pulp is allowed to lie for several days, and when sufficiently dry and consolidated is cut with sabre-like blades or sharp spades in parallel strips as broad as the turves are long. After a few more days' exposure, these strips are cut into turves.

When on account of its watery condition, the peat-pulp is collected in perforated bins, in which it is worked up, it is moulded into turves by means of wooden frames without bases ;

these are placed on the ground or on a bench, and the pulp poured into them. Its surface is levelled by means of a board which is also pressed down on the pulp in the frame to expel the water.

Moulds of several compartments are composed of rectangular wooden frames open above and below, and divided into 16, 28, 36 or more compartments, each the size of a turf. A mould is then placed on a bench, or on a substratum of straw, reeds, &c.; the peat-pulp is poured into its compartments by a shovel, pressed down, and the mould is then removed. In order that the turves may not stick to the sides of the compartments, they are lined with tin, or their bases are somewhat wider than their tops.

Simple moulds resembling those used in brick-making are used by a workman standing before a bench, often made of cast-iron, on which the mould is placed. The mould is of wood, open at top and base, its interior the size of a turf and generally lined with tin. The workman from a heap of peat-pulp on his bench, takes sufficient with both hands to fill the mould, strikes off the superfluous peat with a board, the size of the base of the mould; he then places the board over the mould, turns the latter over, raises it and leaves the turf resting on the board. A second workman takes the board and turf to the drying-ground, and brings back the board. In the meantime the former workman continues to make turves with the mould and other boards.

Experience shows that a simple mould is at least as expeditious as a multiple one, a man, with a boy to remove the turves, preparing 1,000 to 1,500 turves in a day. As moreover the peat-pulp passes again through the workman's hand, and all foreign matter can thus be removed, the turves in that case are more uniform and free from extraneous matter, and as the peat is not poured but pressed into the mould, the turves are denser than in the former method.

(c) **Drying Moulded Turves.**—Moulded turves must be more gradually and carefully dried than those which are cut directly from the bog. When peat-pulp is cut, the turves are left to dry for a few days, and then turned on to their narrow sides; they are then generally piled in superposed rings (as described above, p. 739). They must be turned again once or twice, according to the state of the weather and are stacked when completely dried.

Moulded turves generally dry more quickly than cut turves, especially when they are moulded like bricks and dried like ordinary turves.

When the peat is very watery and moulds of several compartments used, it is better, after the preliminary drying on the ground (which is not required for brick-moulded turves) to place the turves under cover, as they cannot withstand prolonged rain. Turves made in multiple moulds may be entirely destroyed by rain, so that this method can only be adopted in fine weather.

(d) **Quality.**—Moulded turves generally afford a better fuel than cut turves, in ratios of 5 : 3 or 5 : 4. This is due to their greater homogeneity, the removal of extraneous matter, greater density and the use of amorphous peat, which is often wasted when the turves are cut from the bog.

3. *Manufactured Peat.**

Manufactured peat is so prepared as to be capable of competing with other fuels in the market.

Turves cut from bogs or moulded by hand will not bear distant transport, firstly, on account of their large volume compared with their value as fuel, and secondly, on account of their brittleness and property of absorbing much moisture in damp air and of falling to pieces when frozen. These turves are, therefore, saleable only in the immediate neighbourhood of the bog; the price obtained for them being low does not encourage an extensive working of the bog. Owing to the high price of fuel which prevailed a few decades ago, the large demands for industrial purposes and the extensive supplies of peat available in certain districts, the question arose as to whether peat might not be so improved by machinery as to yield a fuel approaching coal in value. Owing to the subsequent depression in the price of fuel, the demand for manufactured peat has somewhat abated, but the industry is still carried on in many places.

In order that manufactured peat may compete with coal and wood, it must be utilizable for heating boilers, preparing gas and paraffin, in metallurgy, &c., and should fulfil the following conditions :—

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* An interesting account of peat manufactured at Schussenried in Württemberg, is given in Baur's Centralblatt, 1881, p. 88.

Density.—The turves must not merely be dense superficially, nor so dense at the surface that the air cannot reach their interior, but be uniformly dense throughout.

Compactness.—The turves must be compact enough not only to retain their shape during transport, but also while being burned.

High combustible power.—During manufacture, the most combustible parts of the peat must be carefully preserved, especially the amorphous peat.

Dryness.—The peat must be thoroughly dried, not only superficially, but also internally ; it should, as far as possible, lose its great hygroscopicity and not swell considerably when exposed to damp and thus become unserviceable.

Quantity.—The manufacture must be so conducted as to yield large quantities of material and be independent of the weather.

The cost of production, including that of supervision, must be sufficiently low to allow the material to compete with other locally used fuels.

The following methods have been undertaken to secure the above conditions :—**contraction, dry pressure, wet pressure and destruction of structure with or without** pressure.

All these methods are, however, too costly to repay the expense unless the price of fuel is as high as during the forties of this century. Several of these methods have fallen into disuse, whilst others have been adopted. The former will, therefore, only be shortly considered, more attention being given to those still in vogue.

(a) **Contraction.**—Challeton at Paris, and Ray at Neuchatel adopted the following method of increasing the density of peat. The turves were cut from a bog, brought to the factory and then cut to pieces by a system of rollers with blades fixed on them ; the material was then treated with running water so as to form a thin pulp, which runs over fine sieves in order to remove all coarse fibres. This fine pulp is then led in canals to a trench one to two feet deep, the bottom of which is covered with reeds or rushes. In this trench the pulp sets firmly, the water draining off through the reeds, and after a few days it can be cut into turves by means of a wooden lattice-frame as broad as the trench, which is pressed down on the peat.

The specific weight of Challeton's peat, according to Schenk 1·1 to 1·2, and to Dullo 1·8, is equal to that of coal. But it is not suitable for fuel, as it burns like charcoal, without any flame, the turves also fall to pieces in the fire and block up the grate.

(b) **Dry pressure.**—In this case the peat is subdivided as finely as possible, thoroughly dried and pressed into turves. The experiments of Exter made a few years ago at Haspelmoor near Munich and some other places, give the best known results of this method. The bog was superficially ploughed by a steam-plough. All the refuse peat was finely subdivided, dried and conveyed to the factory. It was then sifted and thoroughly dried in a specially designed hot-air chamber, which it left with only 10% of moisture, and was then converted into turves by a powerful press.

This product, however, did not answer the purpose intended, as it fell into dust while burning, and was scarcely superior, as fuel, to the best ordinary turves.

(c) **Wet pressure.**—Owing to the obvious advantage resulting from pressing the wet peat, and thus increasing its density, and at the same time its compactness, more attempts have been made in this direction than in any other. No attempt, however, to press raw peat has succeeded, partly on account of the fibrous nature of the peat, which caused it to swell again after the pressure had been removed, and partly because the valuable humus-carbon escaped with the water, and thus the product deteriorated as a combustible. Other kinds of pressed turves were too dense externally, and their interior either did not burn well or else retained too much moisture.

(d) **Destruction of the structure of the peat, with or without pressure.**—It is now everywhere recognized that the structure of the peat must be destroyed before the turves are formed, and that only a moderate pressure, if any at all, is advisable. The apparatus of Schlickeysen and Geysser, Gratjahn and Pilau, Thecke and Sander, Weber and Mattei, are those best known for this method.

(i.) **Method of Schlickeysen*** and **Geysser.**—A vertical axle is moveable by steam-power in a vertical, hollow, cast-iron vessel, with a funnel-shaped top. On the axle are 6 sharp horizontal knives, fitted to it like the thread of a screw, while 6 corresponding knives are on the walls of the vessel. There is also a moveable base, which is attached to the axle and rests on the real base of the vessel, and immediately above it are two holes on opposite sides of the vessel through which the prepared peat passes. The peat placed in the vessel while the axle is in motion is cut into shreds by the knives, which also cut through all pieces of roots; it is at the same time pressed slightly downwards by their screw-like action, and finally passes out through the holes in a round rope-like mass of stiff paste. This runs out continually on to a bench, and is cut into pieces and dried.

FIG. 324.

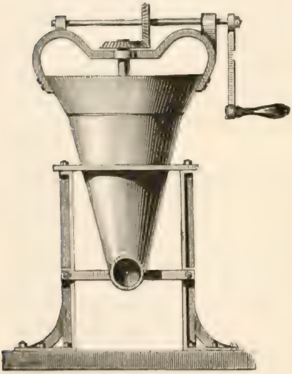
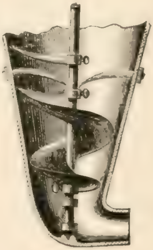


FIG. 325.



Although no water is added to that originally in the peat, the latter is quite plastic. The fresh turves are only moderately dense, though covered superficially with a smooth gelatinous coating they are yet capable of being easily and thoroughly dried. There is no loss of humus-carbon, which during the macerating process becomes attached to the walls of the vessel and issues from it as a glazed coating to the turf. In 12 hours, 15,000 turves, each a foot long can be cut from each side of the vessel, and in favourable weather they dry rapidly with a considerable shrinkage. This turf can be used not only as ordinary fuel, but also in the manufacture of glass and porcelain, it must then be dried in kilns. *Geysser* has invented hand-machines of a similar description to the above, as represented in figs. 324 and 325, and capable of turning out 2,500 to 3,000 turves in a day. These hand-machines have the advantage over that of Schlickeysen, of saving the transport of the wet peat, besides saving fuel, and can be worked on the bog; at the same time they are not applicable in the case of very fibrous peat, or where there are many roots. Geysser dried the peat in an excellent manner in portable drying sheds, consisting of frames like hurdles placed one above the other, and covered with a roof.

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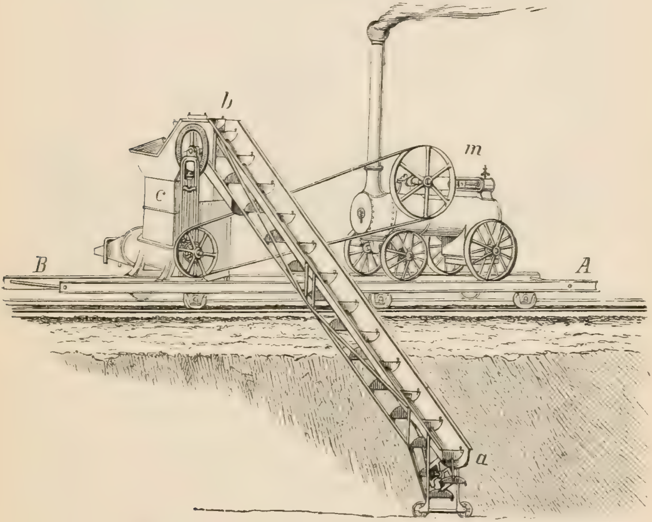
* Leo, Die Kompression des Torfes.

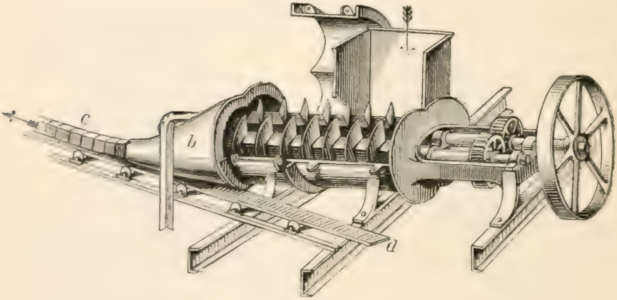
Fig. 326.



(ii.) **Method of Grotjahn-Pilau.**—Figs. 326 and 327 show the machinery constructed by G. Krauss & Co. of Munich.

The elevator *a b* (fig. 326) raises the irregularly shaped pieces of peat to *b*, where they fall into a bin *c*, and hence into the horizontal macerating machine, the interior of which is shown in fig. 327. This is of somewhat similar construction to Schlickeysen's vessel containing a moveable axle with revolving knives. The peat is thus finely subdivided, uniformly mixed together, and finally issues through the orifice *b* (fig. 327), on to a plank *d c*, which is pushed forward on rollers. A workman stands at the orifice of the machine, and cuts the issuing part into turves with a sharp instrument. The elevator and macerating cylinder are driven by a locomobile *m*, and they both stand on a frame *A B*, which can be moved by means of small wheels along a tramway as the digging-ground advances. The plank *d* is taken with the turves on it to the drying-ground, and turned over carefully, and then brought back to the machine. This mode of preparing turves has been extensively employed both in North and South Germany. [Some other methods are given by Gayer.—Tr.]

Fig. 327.



Some progress has certainly been made in the quality of machine-made turf. Hausding[*] states that air-dried machine-turf, with at most 10% of ash has ⅔rds the heating power of superior coal, so that one cwt. of machine-turf is equivalent to ½ — ⅔ cwt. of coal, whilst ordinary turves are equivalent to only ⅓ — ½ cwt. of coal.

[*] Op. cit. p. 720.

It may here be noted that several attempts have also been made to carbonise peat and produce peat-charcoal in order to increase its market value as a fuel.

4. *Peat-Litter.*[*]

Peat is not used for many other purposes besides fuel. Its use, however, for stable litter is increasing in importance, and is especially noticeable here, as there is a hope that by this means the disastrous use of forest litter may be stopped.

Peat forms a much better stable litter than either forest litter or straw, for it is[†] 3—5 times as absorptive of fluids as the latter, and thus prevents any waste of animal manure, either in the form of urine or ammonia. The humic acid in peat also acts beneficially on the salts, alkalis and alkaline earths of the soil. Peat also improves the soil physically more than other litter, retaining moisture in loose soil, loosening binding soil and especially in promoting porosity. Its capacity for heating the soil has been clearly shown in vineyards. The air in stables in which peat-litter is used is free from ammonia and is thus made healthy; the beasts have a dry, soft bedding, the litter is also preferable to other kinds for horses, cattle, sheep, pigs or poultry. Peat is also used in the dry-earth closet system. Only loose textured, mossy or fibrous peat, forming the superficial layer of bogs, is used for litter. In some bogs layers of the fibrous peat and amorphous black peat alternate, preparation of peat for fuel and litter should then proceed simultaneously. The peat should be dried and then finely subdivided in a **peat-mill** (fig. 328) and pressed into rectangular bales weighing 2 to 3 cwt. each. [Such bales of peat-litter are now largely imported from Holland into London, for Omnibus and Tramway Stables.—Tr.]

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[*] Vide Dr. Fürst, die Torfstreu; and also Bayerische's Torfstreu und Mullwerk, Haspelmoor.

[†] According to experiments made by Wollny, Classen and Petermann, the following are the absorptive capacities of different substances.

	Percentage of weight.		Percentage of weight.
Spruce-needles	161	Moss	409
Scotch pine ,,	207	Spruce saw-dust	440
Oak dead leaves	242	Haspelmoor peat-litter	636
Beech ,, ,,	257	Oldenburg peat	659
Wood-wool	285–440	Haspelmoor prepared peat-meal	690
Rye straw	304		

Machines have been constructed for subdividing peat, the commonest of which are represented in figs. 328, 329, the latter

Fig. 328.

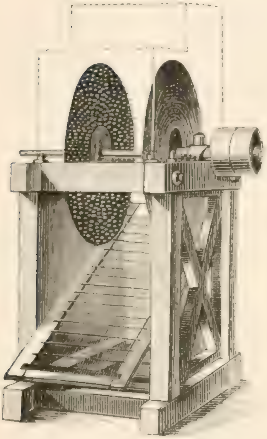
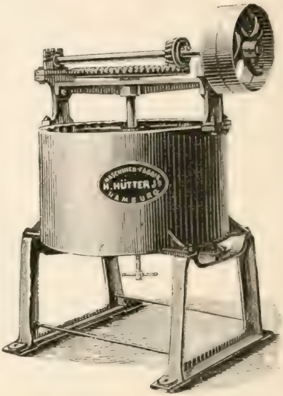


Fig. 329.



being termed the **peat-mill.** The subdivided peat falls from the machines on to a wire sieve, which separates the powdery from the fibrous peat. The latter is used in dry-earth closets. In order to preserve the bales during transport, pieces of undivided peat and laths are placed along their edges. About 70 or 80 bales can be carried by an ordinary railway truck.

From fibrous peat excellent antiseptic dressing for wounds is prepared; the future will show whether it can be used as filling material for walls, roofs, &c.

CHAPTER V.

HUSKING AND CLEANING CONIFEROUS SEEDS.

IN order to obtain coniferous seed it is generally necessary to open cones artificially by means of heat or mechanism. Cones of Scotch pine and spruce open in hot, dry air; larch cones cannot, however, be opened by means of heat without danger of destroying their germinative power, they must therefore be forced open mechanically. Cones of Weymouth and black pines frequently open after merely drying them in the air. It is well-known that silver-fir cones open as soon as they are ripe [so also cones of Deodar and other cedars.—TR.]

The forest owner was formerly obliged to arrange for his own supply of seed; cones were then sown entire, or were opened by exposure to the sun or more frequently by the use of simple heating apparatus, which were constructed by States or private forest owners. When more recently, artificial reproduction gradually displaced natural regeneration and broad-leaved species made way for conifers, while much waste-land has been planted, the demand for seed has increased so considerably that its supply has become an object of trade which competes with the State seed establishments. Many States and private forest owners, therefore, no longer collect their own seed, and seed-husking is now chiefly managed by traders.

[There are several State seed-establishments in France;[*] at Murat (Cantal) and Puy (Haute Loire), for a variety of *Pinus sylvestris* (Pin d'Auvergne); Modone (Savoie) and near Mont Louis (Pyrenées orientales) for mountain-pine, largely used for mountain-reboisement; also at Moutiers (Savoie) for spruce.—BOPPE.]

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[*] For a good description of these, vide *Achat, récolte et préparation des graines résineuses*, par André Thil, Inspecteur des forêts. Rothschild, 14, Rue des S. Pères, Paris.

SECTION I.—SCOTCH PINE AND SPRUCE SEED.

There are various methods for obtaining Scotch pine and spruce seed which are all based on the application of heat to open the cones, and thus allow the winged seeds to escape. Either solar heat, hot-air chambers or steam may be employed.

1. *Solar heat.*

Cones to be opened by solar heat are placed on wire-gratings, arranged one above the other and freely exposed to the sun's rays, or in portable bins covered by wire-gratings. By occasionally shaking the gratings the seeds are made to fall on cloths, or into portable bins, placed beneath them.

A simple method is to place the cones on large cloths spread in a dry place exposed to the sun's rays. The seeds can then easily be sifted from the cones.

Although the success of methods employing merely solar heat depends on favourable weather, and the seeds must remain unutilized for a whole summer and consequently fresh seed is not available for sowing, yet this sufficed for the small demand of earlier times. It is at present rarely employed,* although certainly preferable to all other methods as regards quality of the seed.

2. *Hot-air Chambers, or Seed-kilns.*

Whenever the cones are opened by means of artificial heat, they are exposed on wire-gratings in hot-air chambers to temperatures of 100°, 112° and 145° F., the air being kept as dry as possible until all the seed has been separated. The heat is supplied either from furnaces in the chambers themselves, or by heating apparatus in another chamber from which hot air passes into them. Most German seed-husking establishments follow this method.

It may be objected, that seed when exposed too long to a heat of 100° F. and more, becomes overdried and loses its germinative power. This often happened formerly when the arrangements were defective, but is no longer to be feared, owing to improvements in the system.

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* [The French seed-establishment at Moutiers employs solar heat for spruce seed.—BOPPE.]

The essential conditions of a good seed-kiln are that all the seed may leave the cones and a large percentage of it be fit for germination. The latter condition is secured, if the cones are good, by not subjecting the seed to the hot air any longer than is necessary to separate it from the cones. If this cannot be otherwise secured, the seeds should be allowed to fall on a cool floor. As regards germinative power, the result may be considered satisfactory, when the following percentages of good seed are obtained :—

Spruce	75%
Black pine	75 ,,
Scotch pine	70 ,,
Larch	30–35 ,,

In the interests of economy it should be so arranged that the requisite amount of heat is afforded with the least possible expenditure of fuel and is equally distributed through the hot chamber.

Quality of seed is more important than quantity, if 90% of the resulting seedlings are a centimeter long in eight days a pound of seed will go much further than two pounds of seed of ordinary quality, only 60 to 70 % of which germinates in 14 days.

Whenever the quantity of cones to be opened annually is not very considerable and sufficient capital is not available for a large establishment, the simplest kind of seed-kiln will suffice. A spacious chamber, which can be suitably closed, containing a tiled Dutch stove, is then sufficient. Round the stove are stands, the upper portions of which support easily accessible wire-trays, or the cones are hung in nets from the ceiling. If the floor is paved, ventilators supplied at the four corners of the ceiling for the escape of the vapour from the cones and the heat regulated, good results may be expected.

If there is sufficient space, the stove may be enlarged into a horse-shoe shaped heating-apparatus round the interior of the chamber and sometimes partly sunk into the floor. The stove must be made of brick-work or trachite (*Bachstein*) ; otherwise a steady temperature is not obtainable.

When, however, hot air is admitted into the seed-kiln, an iron stove and hot-air pipes are placed in a separate chamber, from which the hot air passes, as required, into the hot chamber being replaced by the admission of cool air. Most large seed-kilns are made on this principle. As the heating is effected more rapidly the more directly the stove communicates with the air, the apparatus is generally arranged so that the hot chamber is traversed by a long series of hot-air pipes, which only after many convolutions communicate with the chimney of the stove.

Although all seed-husking establishments more or less follow the above plan, they differ from one another in their heating apparatus, arrangement of the gratings, &c., so that hardly any two of them are alike. They may, however, be arranged in groups, according as the wire-trays are **moveable, fixed** or **cylindrical.**

(a) **Moveable trays.**—In this case, the light wooden frames of the trays are moveable and not too heavy for a man to lift easily; they are placed pretty close one above the other, generally on supports above the hot chamber. They can thus easily be removed and replaced for changing the cones. Hundreds of these frames are used in large establishments.

One of the older establishments is at Eberswald (figs. 330, 331): *A* is the chamber for heating, *B* for drying, *C*,*C* for cooling. *A* is surrounded by thick stone walls; within it are two iron pipes (*k*) which are bent back on themselves, their lower parts resting on the stove and their upper ends opening into the chimney (*p*) and they can be cleaned at (*w*). The air in *A*, heated by these pipes, pours through openings *c*,*c*,*c* which can be closed by valves under the trays (*a*), the latter being placed above the cooling-chambers *C*,*C*. The cool air passes into the chamber *A* through tubes (*o*,*o*). The trays (*a*,*a*) rest on supports, and when once the cones are placed on them can be isolated by means of shutters from the action of the hot air except when it comes from below. Between the rows of trays and immediately above the heating-chamber is an open space for workmen, who can thus remove and change the trays. Fresh cones are supplied through leather tubes descending from the ceiling on to the trays.

By constantly stirring the cones with rakes, the seeds are made to fall from tray to tray down to the cooling-chambers *C*,*C*: a supply of cool air is always admitted into the latter in order

Fig. 330.

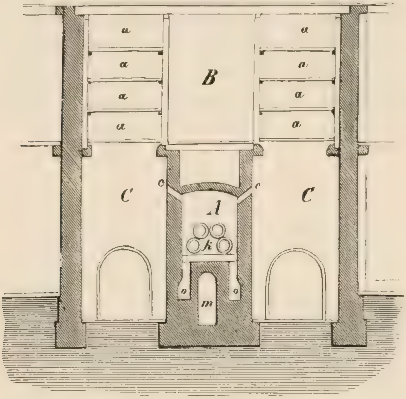
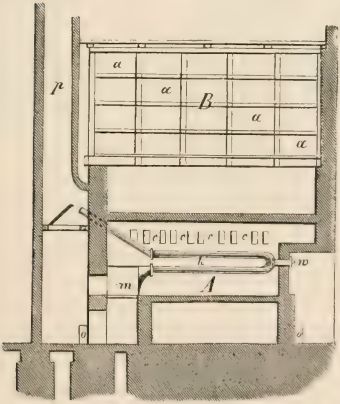

a
a
a
a
B
a
a
a
a
C
o
c
A
k
C
o
o
m

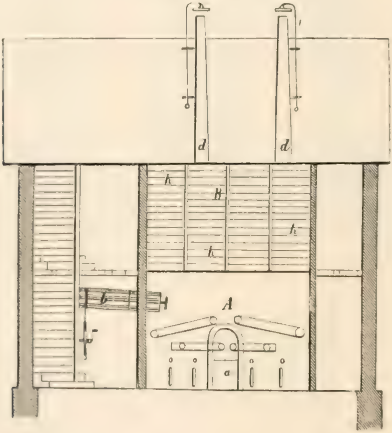
Fig. 331.


a
p
a
B
a
a
k
w
m
A
o
d

that their paved floor may cool the seed, which is from time to time swept out of the cooling-chambers.

Mr. Schott, a seed-merchant of Aschaffenburg, has an establishment somewhat similar to that just described (figs. 332, 333). *A* is the heating-chamber containing the convoluted iron pipes and surrounded by a thick masonry wall which is pierced on two opposite sides by doors opening into the drying-chamber *B*, through which the trays can be removed and fresh ones supplied. As both the heating- and drying-chambers are surrounded by the moderately cool air of the building, the heat is as much as possible concentrated. The stove is at (*a*), the smoke escaping through (*m*). The wooden trays (*h*,*h*,*h*) are provided with a base of thin wooden bars, except the lowest of them which have fine wire-bottoms, to prevent the seed from falling into the heating-chamber. Only a very inconsiderable portion of the seed, however, ever reaches these lowest trays; most of it remains on the upper trays which are not shaken or disturbed in any way until they are removed. When once the cones are opened, the trays on which they lie are removed and the cones shaken on to a floor of wire-grating which is immediately above the revolving hollow sieve (*b*). The cones are raked up and down over this floor so that the seed may all be

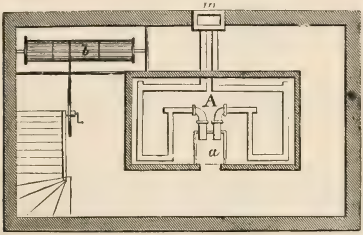
Fig. 332.



removed. The vapour from the cones escapes by means of shafts (*d*,*d*) which can be closed if required; fresh air is supplied by the vent-holes (*o*,*o*,*o*).

This simple apparatus may be taken as a type of numerous private seed-husking establishments, as Geigle's in Nagold, Steiner's in Wiener-Neustadt, &c. The large establishment of Appel, in Darmstadt, is on the same principle. The frames supporting the trays are made of iron; four large stoves in the lower story supply the hot air. Numerous openings with valves regulate the temperature.

Fig. 333.



(b) **Fixed trays.**—Fixed trays are used in buildings with several stories; the heating-apparatus being on the ground-floor, above which are two or more drying-chambers. The floor of each of these is of grating (in the newest establishments of the kind, of thick iron wire, in the older ones of wooden bars), but close enough to allow only the seed and not the cones to pass. The cones are piled a foot deep on the gratings and are constantly stirred, so that they part with all their seeds. The seed falls into the seed-chamber on to a paved floor kept constantly cool by the admission of cold air, and from which it is removed. In the older establishments of this kind, the floors are not completely covered with gratings, but the gratings are surrounded by planked floors and enclosed with planks a foot high.

Although in this system, the different establishments are not so variable as in those with moveable trays, they differ in their respective heating-apparatus.

Sometimes the hot air is distributed by means of masonry pipes which branch into the different drying-chambers. These pipes contain numerous openings through which the hot air passes. Several South German establishments are thus constructed. They have the advantage of regulating the temperature, so that even if heat is carelessly applied, there is not much danger of the seed being overdried; they are not, however, economical as regards heating-power. In order to remedy this defect, several other methods have been adopted of which fig. 334 is a type, representing the establishment of Steingässer at Miltenberg. The stove (*a*) in an underground room *M*, the upper part of which leads into a system of pipes (*b*,*b*) and is surrounded by a cupolaed frame of trachyte which passes into the seed-room *A*, and allows the contained hot air to escape through several long tubes (*k*,*k*) and numerous openings. The channel

FIG. 334.

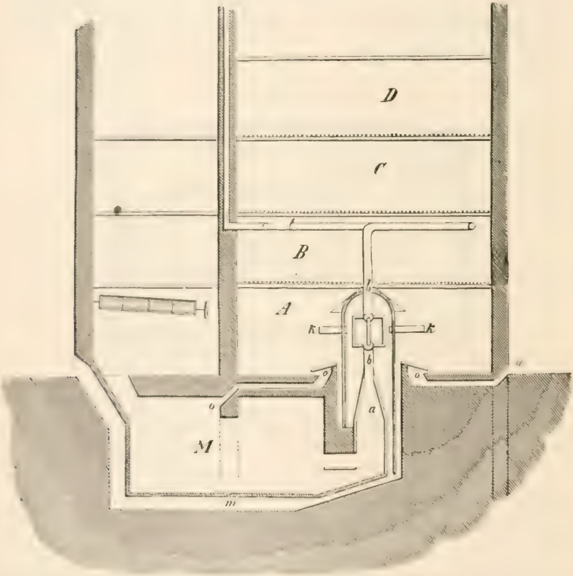
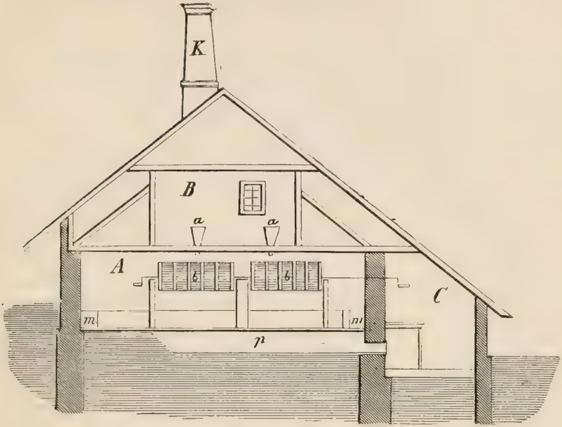
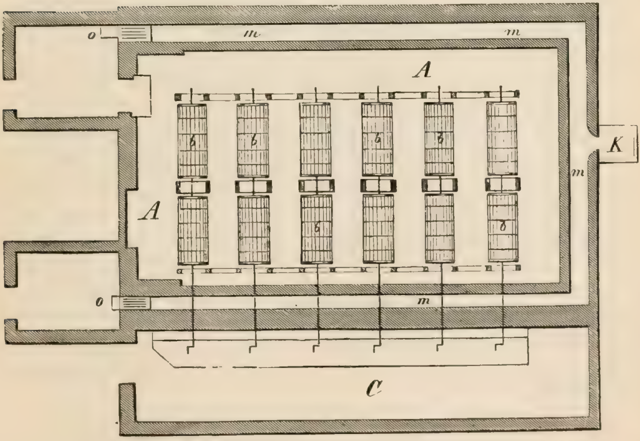


FIG. 335.


K
B
a
a
A
b
b
C
m
m
p

(Elevation.)


o
m
m
A
b
b
b
b
b
K
m
A
b
b
o
m
C

(Plan.)

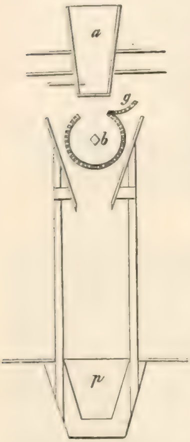
Seed-husking establishment with drum-sieves.

(*m*) admits cool air and (*o*,*o*) are ventilating tubes arranged so as to keep the paved floor cool. *B*, *C*, and *D* are drying chambers.

(*c*) **Drum-sieves.**—Apparatus with drum-sieves differ completely from those described above, and are used in many places, in Silesia, Hannover, Mecklenburg, &c. (fig. 335).

The hot air is then supplied by means of closed pipes (*m*,*m*,*m*) made of trachyte and closed with iron valves, which are situated beneath the drying chamber. The cones are supplied from the floor of a loft *B*, passing through the funnels (*a*,*a*) into the drums (*b*,*b*) which revolve in pairs on a common axle; they are turned by handles in the room *C* so that the seeds may fall through as soon as the cones have opened. The drum-sieves are of wood with wooden gratings secured by several iron hoops. Each drum can be opened (fig. 336, *g*) in order to insert and remove the cones; under each pair of drum-sieves is a masonry or concrete trench (*p*) into which the seed falls, and from which it is removed by wooden scrapers into the chamber *C*, into which the trenches lead. After the seeds have all been removed, the drums are opened downwards and the empty cones removed by the same means as the seed. The drums are turned at intervals of a quarter of an hour, so that the seed soon falls into the cool trenches and being at once removed is not exposed to the hot air longer than is absolutely necessary. This rapid action allows much greater heat to be applied to the cones than in other establishments; recent experience, however, shews that they are not more effective than the latter, which are on the whole preferable.

FIG. 336.



3. *Separation of Seed from the Cones by Steam.*

Cones are opened by steam, when the air round the trays in which they are placed is heated by means of condensed steam.

Steam from a boiler outside the seed-kiln is supplied in pipes running under the trays, it then becomes condensed owing to the comparative coolness of the chamber containing the trays. The steam-pressure being then considerably increased, the heat acquired in the boiler is radiated into the drying chamber by the pipes. In order to increase the heating effect of the pipes, their surface is considerably increased by conducting them repeatedly up and down the drying-chamber.

Keller's well-known wholesale seed-establishment at Darmstadt was the first to carry out this invention of Oberforstrath Braun, and has been working successfully for many years. The first of these seed-kilns was burnt in 1865, and up to that time there were three tiers of piping under all the trays. This, however, did not heat the air sufficiently; in the new works erected therefore, two tiers of piping were placed under the trays, and the other tier moved higher up between them. This gives excellent results. The pipes are of wrought iron and are 200 meters long, with an exposed surface of 87 square meters. The boiler is in a detached house, and also serves to drive machinery used in separating seed from larch-cones; it supplies steam for heating the pipes and the resulting condensed water flows back into the boiler.

The advantages of steam drying over hot air drying are as follows:—

There is no fear of a conflagration in the seed-kiln; by means of in and out draughts, heat can be supplied according to requirements, and the amount necessary for opening the cones is attained in one third the time required by the hot air apparatus, whilst the whole time occupied by the process is shortened by one quarter; the temperature cannot exceed 133° F., so that there is no danger of over-heating the seed. Keller's process gives from 87 to 97% of germinating seeds, which, according to Braun are not only considerably superior in germinative power to seeds from hot air kilns, but can also be kept longer.

4. *Management of Seed-husking Works.*

The system followed in the different seed-husking establishments is of a simple nature. The cones from the store-house are placed in sacks or otherwise brought to the seed-kiln and placed on the trays. After the heat has been applied and the cones begin to steam, all vent-holes must be opened. As soon as the air becomes drier and the cones have been exposed for some time to the heat, they begin to open. This does not generally happen simultaneously on all the trays; the current of hot air is then turned in the direction of the backward trays by opening certain vent-holes, or changing the places of those trays with those where the cones have opened and thus exposing them to the hottest blast.

Management of the heat is the most important point in the kilns. The heat should rise as uniformly and quickly as possible to the temperature most suitable for the apparatus and cone in question. Scotch pine cones require the greatest heat, usually 100°–112° F.; spruce, 90°–100° F.; Weymouth-pine and alder, 66°–77° F. If the apparatus works so well that the seed falls straightway from the cones on to the cool floor and is then removed as soon as possible, higher degrees of heat are admissible: thus in the case of Scotch pine cones, temperatures of 140°–145° may be attained without impairing the germinating power of the seeds, provided that the high temperature is at once reduced to 110° or 120°, as soon as the cones begin opening and this temperature maintained until the end of the operation. In many places, a temperature of 160° is applied, but this is permissible only in the drum process, where the workman is not obliged to turn over the cones inside the kiln, which would be impossible at such a temperature.

As empty cones are generally used for fuel and give out heat quickly, a few cones should be added to the fire every 15 minutes or so. The stoker must attend carefully to the direction of the wind, &c., and endeavour as much as possible to supply the requisite amount of heat.

The time required to open the cones thoroughly depends on several conditions. First, the species of cone; Scotch pine cones require the highest temperature, whilst cones of other species open more readily. Cones open more readily when collected after November; frost has a considerable effect on the opening of the cones; thus, in mild winters with little frost, the business of seed-kilns is considerably delayed; cones open more freely when they are brought damp and cold from the store-room into the heat of the kiln, and have not been preliminarily heated. Finally, the kind of seed-kiln in use and the manner of conducting the business influences the time required for opening the cones; if the work proceeds day and night without interruption and the kiln is properly heated, Scotch pine cones require 10 to 12 hours, on the average, before they open. Sometimes they require fully 24 hours and under the most favourable conditions eight hours.

In order to guard against over-heating by the workmen, Keller in Darmstadt has an electric bell in his office communicating with a metallic maximum thermometer in the kiln.

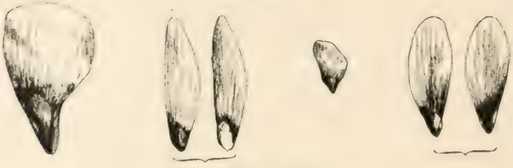
The cones on removal from the trays are usually thrown on to a grating so that the seeds may be separated from them; they then always retain a few seeds and in order to secure these, they are placed in a drum-sieve (fig. 335, *b*), which is made to rotate.

This consists of a cylinder with wire sides, open at both ends, and there are often projecting bars fastened here and there to its axle inside the cylinder which assist in shaking the cones. It is turned slowly by means of a pulley and belt. The cones are poured into the drum-sieve through a hopper and are so thoroughly shaken within it, as to part with all their seeds. The seeds fall on to the floor and the empty cones pass out at one end of the drum-sieve which is slightly inclined in that direction, through a second funnel, into the store-room for empty cones.

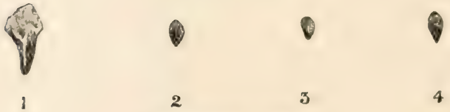
Seeds of conifers are winged; it is however preferable to sow them without wings, sowing being then more uniform and the seed better covered with soil, the projecting wings are also more readily seen by birds than the little seeds. The wings must therefore be removed in order to prepare seed for the market. All seeds, however, cannot be completely deprived of their wings, for in many cases the union between seed and wing is so close, that the latter can be only forcibly removed, which may notably reduce the value of the seed. This is the case with silver-fir and larch seed. The wing is not closely united to the seed in Scotch pine and spruce seed and is easily removed (fig. 337).

Removal of the wings of Scotch pine and spruce seed may be effected in various ways. On a small scale and if it is considered sufficient to remove the greater part of the wing, leaving a small fragment attached to the seed, the **dry process** is employed. In this case linen sacks are half filled with seed (the mouth of each sack being tied) and beaten with light flails, being turned and shaken and rubbed until the wings are removed. In wholesale establishments a different method is usually employed, termed the **wet process**, which gives quicker results. The seed is then piled 6 to 8 inches high on a paved or planked floor, sprinkled lightly with water from the rose of a watering-pot and then energetically beaten with leather flails. In many seed-depots hardly any water is used and yet the wings are completely removed.

FIG. 337.



Winged Seeds.



Seeds prepared for sale.

1. Silver Fir. 2. Scotch Pine. 3. Larch. 4. Spruce.
Drawn by R. S. Troup.)

In order to obtain clean silver-fir seed, more trouble must be taken. The moistened seed must then generally be heated, so that very clean silver-fir seed is regarded with suspicion.

Objection is frequently made to the wet process, that it prejudices the germinative power of the seed. This objection is justified, if the damp seed is kept in heaps and allowed to ferment so that the wings may separate from the seed without any further mechanical treatment. If, however, the method already described is followed and no fermentation allowed, the damping being merely auxiliary to the threshing, clean seed with good germinative power is obtained.

An excellent method for nearly all winged seeds is to put them between the stones of a flour-mill, placed the right distance apart. As then the process is merely a dry one, there is no danger of the germinative power of the seed; it is, however, difficult in this way to produce thoroughly clean seed.

Once the wings have been severed from the seed, they must be removed in order to obtain clean seed. This is effected either by swinging the seed on a wooden tray, or tossing it with a wooden winnowing-shovel, which removes both the wings and light worthless seeds. As a rule, however, the seeds are placed in a modern corn-sifter, provided with several graduated fine wire-sieves. This completely separates all impurities and the worthless seeds from the good seed, the workman being careful to turn the machine slowly.

SECTION II.—SEPARATION OF SEED FROM LARCH CONES.

The method described in Section I. refers only to Scotch pine and spruce; it is not applicable to larch cones, which cannot be completely freed of seed by artificial heat without damaging its germinative power. Only the upper part of larch cones opens when subjected to heat, the base of the cones, which contains most of the seeds, remaining closed. Larch cones must therefore be torn open in machines, clean seed being obtained only after much troublesome manipulation.

Formerly, larch cones were placed in stamping-mills, where they were completely crushed, or apparatus used somewhat resembling turnip-cutting machines. In these, two rollers of different diameters, provided with fairly contiguous, sharp knives, an inch long, are turned in the same direction on their axles, leaving only space enough between them and their corresponding knives for the wooden axes of the cones to pass. The scales and seeds of the cones, which enter the machine from above the rollers, are thus separated from their axes. This process, however, destroys much seed.

More recently use has been made of hand-machines of similar structure to the above, but in which the knives are replaced by stout iron pins, the ends of which are bent into hooks, and inserted on two rollers, one of which is 8 to 10 inches larger in diameter than the other. The cones are then torn instead of being cut, and there is not so much refuse mixed with the seed, and less seed is destroyed than by the machine with knives.

Much larch seed is exported regularly from the Tyrol. In order to remove the seed, little water-wheels are suspended in the rapid torrents, on the axles of which are rapidly rotating tin cylinders. The cones enclosed in these cylinders are violently rubbed against one another, and the seed set free. In order to remove the last few seeds from the cones, the latter are simply pounded. One of the best stores for Tyrolese larch seed is that of Jennewein, at Insbruck.

[In French Savoy and Dauphiny, larch seed is collected by peasants between December and February; during the prevalence of the comparatively warm south wind, the cones drop their seeds on to cloths spread under the trees on the snow. This seed is said to germinate much better than that purchased from seed-establishments.—Boppe.]

The apparatus employed by Appel, at Darmstadt, which resembles that used by the Tyrolese, consists of wooden drums, which are driven by steam and made to rotate rapidly on their axles. Their internal surface, as shown in fig. 338, is covered with little sharp, projecting cones, against which the larch cones are rubbed, but the mutual friction between the cones is more effective than the action of the internal surface of the drums.

Apparatus worked by steam for opening larch cones is generally based on a continual friction between their scales, and consequent removal of the seed without injuring it. That used by Keller at Darmstadt consists of a hollow wooden drum (fig. 339), which is firmly fixed in a vertical position, and at its axis is an iron rod provided with four arms *a*, which support four closely-toothed iron rakes *b*, parallel to the internal surface of the drum. This revolves rapidly on its axle *m n*, larch cones supplied from above are so thoroughly rubbed together and to a certain extent torn to pieces, that they part with all their seed which collects at the bottom of the drum, from which it is then removed.

The sides of this drum are composed of plates of iron which are not quite juxtaposed, finer refuse therefore escapes through the slits between them. Under the drum large sieves are kept in constant motion backwards and forwards. This apparatus of Keller's is preferable to all others yet invented, as it removes the seed in less than half the time taken, for instance, by the Tyrolese method.

Larch seed, when freed from the cones, is mixed with pieces of wood and scales of various sizes, and any amount of dust, from which it must be cleaned. The process of cleaning is therefore a most difficult and tedious business, for there are in the mixture pieces of scales of the same size and weight as the seeds; up to the present time, therefore, it has not been considered possible to obtain really clean larch seed. In order to sift the seed hand-sieves are first used and then a corn-sifter. The sifting process is therefore tedious and the workmen must show much patience. In some places (the Tyrol, for instance) the broken-up cones are placed with water in a tub; the pieces of wood and scales sink to the bottom, whilst the seeds float on the surface and are then scooped off and dried, the dried seeds finally passing through a corn-sifter. This wet process of cleaning is often regarded with suspicion from fear of injuring the germinative power of the seed, but there appears to be no ground for this, provided the seeds are afterwards thoroughly dried.

Fig. 338.

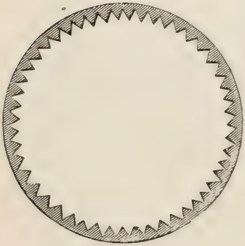
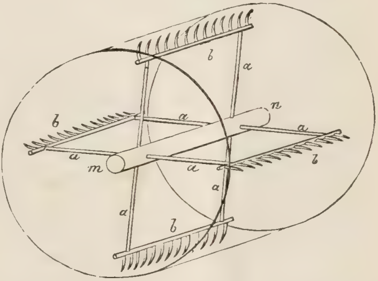


Fig. 339.



In Keller's seed-depot a small mill is used for removing the wings from larch seed, the grinders being made of vulcanised caoutchouc and as far apart as the length of the seeds; the wings are thus removed by friction. A fly-wheel working under the exit-funnel thoroughly separates the wings, dust and worthless seed from the good seed.

Another method for husking larch seed is that of Oberförster Krombelbein at Varel in Oldenburg. Cones plucked late in the season from healthy larch trees, which have been subjected to winter frost, are exposed to the sun's rays in bins covered with wire frames ; seed is thus obtained from the upper part of the cones. In order to open the hard, resinous base of the cones they are submerged in water for 24 hours in covered baskets and after exposure to the air are again placed in the sifting bins. This process is repeated till all the seed has been separated. It is, however, clear that this method, which gives excellent results, can only be adopted on a small scale.

SECTION III.—NET YIELD OF SEED.

The net yield of seed obtained from a certain quantity of cones depends on several circumstances. The system of husking followed is most decisive in this respect ; then the condition of the cones (whether harvested in autumn, mid-winter, or in dry, spring weather, after some of the seeds have left the cones). The size of the cones and the number of seeds they contain also vary in different years, for in really good seed-years cones are often smaller than usual and yet contain more than the usual number of seeds. Lastly, the method employed for removing the wings, and the comparative thoroughness with which this is done, greatly affects the yield.

It is not, therefore, surprising that the yield of different seed establishments in different years should vary considerably. The following table gives the average weight of different quantities of cones and seed :—

Species.	Weight of fresh cones.		Weight of sifted seed from—		Weight of sifted seed.	
	100 liters.	One bushel.	100 liters of cones.	1 bushel of cones.	1 liter.	1 quart.
	kg.	lb.	kg.	lb.	grams.	lb.
Scotch pine	50—55	40—44	0·75—0·90	·60— ·72	500—510	·96— ·98
Spruce ...	25—30	20—24	1·23—1·70	·98—1·36	560—576	1·08—1·09
Larch ...	36	29	1·80—2·70	1·44—2·16	500—510	·96— ·98
Silver-fir ...	25—30	20—24	1·50—2·25	1·20—1·80	300—410	·58— ·79

The concluding table gives the weight of sifted seed without wings of the different species obtained from a certain weight of winged seed, and the number of seeds in a fixed weight of sifted seed.

Species.	Weight of sifted seeds.		Average number of seeds.	
	from 1 kilog. of winged seed.	from 1 lb. of winged seed.	in 1 kilog.	in 1 lb.
	kg.	oz.		
Spruce	0·55	9·6	120,000	54,500
Silver-fir...	—	—	22,000	10,000
Larch	0·80	12·8	165,000	75.000
Scotch pine	0·70	11·2	150,000	68,000
Black pine........ ...	0·60	9·6	48,500	22,000
Mountain pine	0·65	10·4	125,000	56,700
Weymouth pine ...	0·50	8	61,000	27,700

[The figures for Black, Mountain and Weymouth pines were kindly supplied by Mr. Appel of Darmstadt, those for larch partly by Dr. Schlich ; the rest are from Gayer.—Tr.]

CHAPTER VI.*

EXTRACTION OF OIL OF TURPENTINE AND ROSIN FROM CRUDE RESIN.

SECTION I.—PROCESS OF MANUFACTURE.

CASKS of crude resin continue to reach the factories at La Teste from March to October, the last consignments being dark-coloured and inferior in quality. From it, oil of turpentine, the chemical formula for which is $C_{10}H_{16}$ is distilled, leaving deposited an oxidised substance which is solid at ordinary temperatures and termed rosin, or colophany.

These substances are separated from one another in the following way:

i. By melting and filtering the crude resin, so that the water, sand, pieces of bark and other impurities† are separated from it.

ii. By distilling the crude resin, the oil of turpentine and colophany are separated from one another, as these substances have different boiling points.

The crude resin, after being passed through straw filters, if sufficiently fluid for this to be done, is placed in an uncovered vat (fig. 340, No. 1) and heated until it is completely liquefied. This allows heavy substances, such as sand, &c., to fall to the bottom of the vat, while light impurities, chips of wood, bark, &c., float on the surface of the melted resin. This is a very delicate operation, as if heated unequally, the resin is liable to catch fire.

The impurities are then separated from the resin, either by ladling it through straw-sieves, or passing it through a grating into a second vat. The operation of heating and filtering goes on a day in advance of the distillation, so that three vats are required, No. 1 vat being always used for boiling and the other two vats, alternately, as reservoirs from which the resin is ladled into a small tank from which it is passed through a tap to the retort shown in fig. 340.

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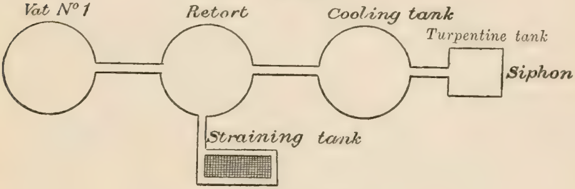
* [This account is mainly taken from papers by N. Hearle and E. McA. Moir in the *Indian Forester*, June and July, 1895. Both these gentlemen as well as the translator in 1894 visited a resin-factory at La Teste, near Arcachon, belonging to Mr. Lesca, and the information given in this chapter has all been supplied through his kindness.—TR.]

† Chiefly larvæ of insects.

This is the method employed late in autumn, when the resin contains many impurities. Earlier in the year, it is passed directly from vat No. 1 to No. 2, a retort in which it is distilled, the arrangement of the vats then being as shewn in fig. 340.

The resin in the retort is heated to a temperature of about 185° F., steam (by the use of which 30 % more turpentine is obtained) being admitted through a pipe. From this retort, vapour of the oil of turpentine and water-vapour pass through a coil of tubing into a cooling tank, where they are condensed; they are then drawn off into a smaller tank, the water remaining below with the turpentine floating on it, owing to the lower specific gravity of the latter. The oil of turpentine is then run through an over-flow pipe into a zinc vessel mounted on a truck, and conveyed by means of a tramway to the turpentine shed, where it is pumped into large metal tanks, measuring 10 feet by 6 feet by 6 feet, from which it is drawn, as required for sale, into old Spanish wine-casks. No system of purifying is in practice, and it is sold just as it issues from the still.

FIG. 340.



(After Hearle.)

The water, which is removed by a siphon from below the turpentine, passes after use through a series of shallow open tanks in a court-yard, from which it is pumped by a small steam engine into an elevated reservoir; it is then used again for cooling the turpentine. The engine also drives steam into the distilling retort.

The liquid colophany, after distillation of the turpentine, is allowed to flow from the base of the retort by removing a wooden plug stamped with clay. It runs into a straining tank, passing over a very fine copper wire-sieve, which catches most of the impurities it has still retained; the rest falls to the base of the straining tank, in the form of a black deposit resembling pitch. The straining tank has a tap placed about half-way down, through which the liquid colophany passes during autumn into another vat, from which it is ladled into large casks containing about 800 lbs.

During summer, however, after a sample has been taken out in a tin mould, the rest of the colophany is at once ladled from the straining tank into buckets; it is then carried to an open court-yard, where it is poured into open shallow metal pans about two inches deep and slightly smaller in diameter than the casks in which it is finally packed for sale. It there cools into cakes which are exposed to the sun till sufficiently bleached; they are then placed, one above the other, in the casks and eventually unite into a single mass.

Great attention is paid to uniformity of colour in each cask, the sample shown to the purchaser being the worst coloured in the cask. The colophany goes into four main classes, for spring, summer, autumn and winter, the first being lightest coloured and most transparent; and the last, made chiefly of *barras*, being darkest. The tints vary from very pale transparent yellow to dark amber. When nearly black it is termed *brais*. Great stress is laid on transparency, denoting purity of the samples, as well as on their light colour. The dark amber-coloured colophany is worth only one third the value of the palest brand, the prices varying from 4*s*. to 12*s*. 9*d*. per 100 lbs.

Besides the main classes of colophany, the commercial grades range from A. the darkest, to N, extra pale, superior to which are W. window-glass and W. W. water-white. These are American brands which have been adopted in France.

A barrel of 520 lbs. of crude turpentine yields 364 lbs. colophany, 110 lbs. oil of turpentine and 46 lbs. refuse. The oil of turpentine sells at about 25*s.* per 100 lbs. Most of the manufactured produce goes to Bordeaux, whence it is shipped to the principal European countries, or used in France. Most of the British supply of rosin at present comes from America, being 1,429,431 cwt. in 1894, while 31,261 cwt. came from France, and 2,797 cwt. from other countries, the whole being valued at 331,486*l.*

The quantity of oil of turpentine imported into the United Kingdom in 1894, was 406,877 cwt. valued at 431,382*l.*, also chiefly from America.

SECTION II.—COMMERCIAL PRODUCTS FROM THE CRUDE RESIN OF THE MARITIME PINE.*

The different products of crude resin are:—

Galipot.	*Brais.*
Oil of turpentine,	Turpentine paste,
Colophany.	Pitch.

Galipot is dried resin picked from the tapped trees, and is used in certain varnishes, also in naval construction, especially in Holland, for painting ships and masts.

Oil of turpentine is distilled from crude resin, and is used chiefly in oil colours, varnishes, and medicine.

Colophany is the best part of the residue after distillation of crude resin, and is used for papier-mâché, sealing-wax, &c.

Brais is obtained by heating in a retort the straw sieves used in filtering the resin and also pine-roots. It is used in making torches, and is run into small square boxes round four or five wicks, and these are lighted on frosty nights, burning with a dense smoke, which protects vineyards from frost; it is also used for soldering metals, or may be made into pitch.

Turpentine paste is used for varnish, sealing-wax, lithographic ink, &c. There are three kinds:—The ordinary quality is obtained after crude resin has been filtered but not distilled. *Pâte au soleil* is obtained when crude resin is exposed to the sun's heat in vessels filled with holes, through which the more fusible portions exude, forming the paste in question. When casks full of crude resin are exposed to the sun, the portion exuding through the staves is termed *Pâte de Venise*. The comparative values of these three kinds are as 37 : 40 : 250, these numbers in francs representing the value in each case of 100 kilograms.

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* From Boppe, op. cit.

By burning the roots and stumps and the residue from the factory, in closed masonry chambers separated by metallic walls, **lamp black** is obtained. Finally, by distilling pinewood, pine oil is obtained, which may be used for lighting purposes, or as an antiseptic for preserving wood when used in the open.

INDEX.

A.

Absorption of water by wood, 52
Acorns, date of ripening, 550
,, used for pannage, 564
Advertising sales of wood, 478
Air-dried wood, 27
Alburnum, 15
Anatomy of wood, 5
Anobium sp., 87
Antiseptic treatment of wood, 659
Anvil stocks, 125
Auctions of timber, 455
Autumn wood, 9
Axe, resistance of wood to, 36
Axes, 193, 211, 227

B.

Bahla, 484
Balks, 107
Bamboos, 87, 163
Bandboxes, 150
Band-saws, 689
Bark, other uses besides tanning, 515
,, removal of, 257
,, for tanning, 483
Barrels, 146
Bast, lime, 656
Battens, 109
Bean-sticks, 165
Beech-nut oil, 569
Beech-nuts for pannage, 564
,, date of ripening, 550
Bentwood for furniture, 46
Bilberries, collection of, 655
Bilberry bushes for litter, 601
Bill-hook, 198, 228
Birch-bark, 509, 515
Birch oil, 515
Birdseye maple, 65
Blasting stumps and roots, 259
Blythe's system of injection, 663
Boards, 110
Boat-building, 125
Bogs, 720
Bole, cleanness of, 21
Booms in timber floating, 383, 385
Boucherie, 661
Bracken, 618
Branches for litter, 602, 613, 618
Briar-wood for pipes, 157
Bridges, timber for, 122
Broom for litter, 600
Brooms, 156, 166
Brushwood, 250, 272
Burnettising wood, 661
Burrs, 65
Butchers' blocks, 141
Butts, 249, 270

C.

Cabinet-making, 133, 134
Canals, influence on timber-transport, 428
Carbonisation of wood, 693
Carriage-poles, 140
Cart traffic, 321
Casks, 142
Catechu, 484
Cellulose, 162
Charcoal, 693
Children's toys, 157
Chutes, timber, 288
Cigarboxes, 173

Circular saws, 688
Cleanness of bole, 21
Cleaving-axe, 211
Climbing-irons, 75, 238, 553
Cloven timber, 111, 258
Colophany, 28, 770
Colour of wood, 59
Compass timber, 129
Cones, collection of, 555
Coniferous seeds, 751
Contract, sale by private, 46
Contractors, timber work by, 189
Conversion of wood, 243
  ,, general rules for, 264.
Coopers' wood, 142
Cordwood, 167, 295
Cranberries, 655
Crate-wood, 165
Credit in sales of wood, 477
Creosoting wood, 662
Cubic contents of wood, 302
Cup-shake, 64, 247
Curls, 65
Curved timber, 129
Cylindrical shape of bole, 22

D.

Damage to wood by fungi, 71
  ,, ,, ,, game, 69
  ,, ,, ,, insects, 86, 95
Dams for timber floating, 361
Dead wood, 572
Deals, 110
Death-watch beetle, 87
Decay in wood, 77
Defects in wood, 61
Depots for timber, 274, 397, 429
Disposal of wood, 441
Divi-divi, 484
Durability of timber, 79
Dry fallen wood, 572
Dry rot, 93
  ,, wood, 27, 572
Dynamite for splitting stumps and roots, 261

E.

Ebony, 28
Elasticity of wood, 40
Epping Forest, 563
Even-grained wood, 60

F.

Faggots, 252, 262, 298
Fascines, 313, 379
Felling rules, 236
  ,, trees, 175
Ferns, 600, 618
Field-crops in forests, 536
Firewood, 167, 212, 251, 257, 295
Fissibility of wood, 39
Flexibility of wood, 42, 59
Floating wood, 357, 421
Flutes, wood for, 157
Forest devil, 216
  ,, litter, 579
  ,, of Dean, 563, 600
  ,, roads, 309
  ,, tramways, 340, 421
Frost-crack, 62, 74
Fruit, edible forest, 655
  ,, of forest trees, 546

G.

Galls, oak, 485
Game in forests, 482
Glaziers' wood, 154
Grass-cutting in forests, 530
Grass-seeds, 649
Gravel, 576
Grazing, forest, 516
Green timber, 27
Grubbing up stumps, 231
Guaiacum wood, 67
Gunpowder for blasting stumps and roots, 260
Gunstocks, wood for, 156

H.

Handles of tools, 141
Hardness of wood, 34
Hardwoods, 16, 34, 168
Hawkeye machine, 214, 232
Heartshake, 61
Heartwood, 9, 15
Heating-power of wood, 97
Herbage in forests, 651
Hook-lever, 277
Hoops for barrels, 147
Hop-poles, 165, 256, 271
Humus, 580, 590
Hurdle wood, 165

I.

Implements, felling, 192
Injection of wood, 659
Instruments, action of, on wood, 36
Internal bark, 70

J.

Jarrah wood, 89, 117, 127
Jhuming, 537
Joiners' wood, 133

K.

Knee-pieces, 130
Knoppern-galls, 485, 654
Knottiness, 67
Krempe, 277
Kyanising wood, 662

L.

Lamp-black, 168
Land-transport, 308
Larch bark, 509
Laths, 110
Lead pencils, 153
Leaf-fodder, 533
Length of stem, 19
Lime-bast, 656
Litter, forest, 579
Logs, 107, 249, 268
Lopping branches, 238, 613
Lucifer matches, 150, 152
Lymexylon navale, 87

M.

Machines for uprooting stumps, 214
Machine saws, 205, 684
Manual labour, 176
Markets for timber, 470
Mast, oak and beech, 563
Masts for ships, 131, 133
Matches, lucifer, 150, 152
Merulius lacrimans, 93
Mining timber, 121
Minor forest produce, 481
Mistleto, damage by, 70
Model-making 136
Mosses, 596, 653
Moss-litter, 596
Myrobalans, 484

N.

New Forest, 563, 600, 602
Numbering hammers, 300

O.

Oak-bark, 486
Oars, wood for, 149
Occlusion of wounds, 65, 75, 76
Oil of turpentine, 28, 83, 770

P.

Packing-cases, wood for, 137
Pannage, 563
Paper manufacture, 160
Paper-pulp, 160
Park-palings, 166

Parquetry, 134
Pasture, 516
Pavements, wood for street, 118
Pea-sticks, 165
Peat, digging, 720
,, litter, 749
Piano-fortes, wood for, 137
Pigs in forests, 564
Pitch pine, 116, 633
Pit-props, 93, 121, 168, 269, 643
Planing machines, 691
Planks, 110
Pliability of wood, 42
Poles, 200, 271
Pony saws, 687
Private contract, sale by, 463, 467
Ptilinus sp., 87
Pyngado wood, 117
Pyroligneous acid, 168

Q.

Quarrying stone, &c., 576

R.

Rafting timber, 408, 411
Railway-carriages, wood used for, 141
,, sleepers, 91, 92, 118, 330, 660, 669, 673
Railways, influence on the timber trade, 427
Red-rot, 71
Reserve material in wood, 28
Resin-galls, 71
,, in wood, 28, 43, 101
,, tapping, 632
Resistance to strains, 47
Rhytidome, 41
Roads, 309
Root-rot, 73
Rosin, 28, 35, 83, 770
Royalty on wood, 451
Rudders, 149

S.

Sabots, 155
Sales of wood, 441, 447
Sale-lots, 292, 475
Salep, 656
Sand. pits for, 576
Sapwood, 15
Saws, 199, 288
,, resistance of wood to, 37
Saw-dust, 164
,, mills, 85, 199, 254, 288, 446, 676
,, sets, 208
Scantlings, 110
Sealed tenders for wood, 461, 466
Season for felling, 219
Seasoning wood, 50
Seeds of conifers, 751
,, ,, other forest trees, 546
Seed-kilns, 752
Shingles for roofs, 148
Ship-building, 125, 269
Shoemakers' pegs, 153
Shrinkage of wood, 53
Sided timber, 107
Silver grain, 61, 134
Slack barrels, 146
Sledges, 140, 280
Sledge-roads, 314, 322
Slides, timber, 324
Sliding logs, 285, 288, 324
Softwood, 16, 34, 168
Sorting wood, 267
Sounding boards, 43
Soundness of wood, 102, 114
Spars, 131
Specific gravity, 23, 80, 98
Split wood, 147
Spokes for wheels, 140, 167
Spring-wood, 9
Stacking wood, 267
Stacks of wood, 295, 439
Stakes, 165
Star shake, 61
Staves for casks, 142
Steaming wood, 46, 59
Stone quarries, 576
Storing seed, 557
Straightness of stem, 20

Street pavement, 118
Strength of timber, 46, 48, 49, 113
Stumps, 231, 234, 251, 259
Sumach, 485
Summer-felling, 52, 224
  ,, wood, 9
Superstructure, 111
Swelling of wood, 57
Swine in forests, 564

T.

Tanks, 373
Tanning bark, 483
Tap-roots, 18
Tar, 168
Teak wood, 127
Telegraph-posts, 256, 271, 660, 669
Tenacity of wood, 47
Teredo, 89
Texture of wood, 59
Timber-assortments, 248
  ,, chutes, 288
  ,, slides, 324
  ,, trade, 471
Tools, wood for handles of, 136
Toys, children's, 157
Tramways, forest, 340
  ,, wire, 352, 421
Transport, 308, 357, 479
Transverse strength of wood, 48
Tree-props, 161
Trenails, 153
Truffles, 654
Turf, 720
Turnery, 158
Turpentine, oil of, 770
Twisted fibre, 66, 247

U.

Unsound wood, 61

V.

Valonea, 484
Valuation of wood, 305
Vanillin, 653
Veneer, 135, 690
Venetian blinds, 138
Vine-stakes, 92, 166
Violet powder, 656
Violins, 138, 154

W.

Wages, 181
Warping of timber, 58
Water-pipes, 117
  ,, transport, 357
Wattle fences, 124
Wavy wood, 65
Wedges, 210
Weight of wood, 33
Weirs, 374
Wheels, 139
Wheelwrights' work, 139
White ants, 88, 659
  ,, piped wood, 74
  ,, rot, 71
Wind-mills, 124
Windsor Forest, 600, 602
Winter felling, 82, 223
Wire-tramways, 352, 421
Withes, 166
Wohmann's machine, 217, 233
Wood-assortments, 268
  ,, carbonisation, 693
  ,, carving, 155, 157
  ,, depots, 429
  ,, engraving, 158
  ,, gas, 168
  ,, plaiting, 160
  ,, sap, 81
  ,, transport, 308
  ,, tapestry, 149
  ,, wool, 653
Wooden shoes, 155, 157
Worm-eaten wood, 86, 95

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